



*Conseil Permanent International pour
l'Exploration de la Mer*

CHARLOTTENLUND SLOT — DANEMARK

RAPPORTS

ET

PROCÈS-VERBAUX DES RÉUNIONS

Volume 148

CONTRIBUTIONS

TO

SYMPOSIUM ON SALMON AND
SEA TROUT 1958

En Commission chez

ANDR. FRED. HØST & FILS

COPENHAGUE

Prix: Kr. 16.00

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PREFACE

At the Bergen meeting of the International Council for the Exploration of the Sea in 1957, it was arranged that at the next meeting a symposium should be held on two aspects of salmon biology. The topics chosen were methods of tagging and the problems of stock replenishment either by natural or artificial methods. These topics are in fact related, for the success of the latter operations can often best be judged by techniques dealt with under the other heading.

The symposium was held at Charlottenlund on 27. and 28. September 1958, and was well attended. The papers were well presented and discussions on them were informed and stimulating.

The papers given are here published upon the recommendation of the symposium, which was accepted by the Salmon and Trout Committee and endorsed by the Consultative Committee. It is felt that they will be of value to biologists in many countries, and perhaps not only to those who are concerned with salmon research, for many of the problems dealt with have their applications to other fisheries as well. The reader may feel that the particular value of this symposium lay in its bringing together so many people from both sides of the Atlantic in a discussion of their common problems and the opportunity it afforded for a comparison of the methods and results obtained in different countries. In particular the inauguration of studies in population dynamics, especially in U.S.S.R. and Canada, opens up a field in which it is clear that further advances will yield great practical benefits.

G. Nikolsky, Chairman.

F. T. K. Pentelow, Rapporteur.

CHAIRMAN'S INTRODUCTION

The problems of salmon ecology which have been dealt with in this Symposium are closely associated with those of raising the productivity of the stocks of the Atlantic salmon (*Salmo salar* L.). It is well known that the fishery for this valuable species is now so intense that it is difficult to obtain increased catches, in which all countries are interested, without applying special measures.

An increase in productivity of the salmon stocks can be achieved in a number of different ways. Where the natural spawning grounds are in good condition and access to them is unrestricted, provision of facilities to permit sufficient spawners to reach the spawning grounds, creation of favourable conditions on the spawning grounds themselves, and protection of the salmon from predators, are particularly important. Another method is to exploit the fishery rationally at a period of the salmon's life when the fish is most valuable, i.e., when it has reached full maturity. This seems to be very important in the case of the Baltic salmon stock. Still another method is, of course, artificial propagation.

According to the decision made at the 45th meeting of ICES this Symposium is limited to the consideration of those problems alone which, in one way and another, are connected with two practical problems, viz.:—

1. the effectiveness of liberating fry, parr or smolts of salmon and sea trout under different conditions, and
2. tags for salmon and trout and their relative effectiveness.

Both of these are important if we are to solve the problem of increasing the productivity of the salmon stocks.

The efficiency of our work on salmon culture is determined by a solution of the liberation problem, which in turn requires a knowledge of the natural mortality, particularly mortality caused by predation. In turn this is connected with smoltification and a number of other problems.

Of no less importance is the question of tagging. Tagging is used to determine the efficiency of our work on fish culture, mortality rates, the behaviour of the young salmon in streams, and so on. Serious attention must, therefore, be paid to the improvement of tagging methods.

Papers presented to the Symposium have been grouped as follows:—

1. Tagging methods
2. Smoltification and liberation
3. General questions and recommendations

A working group, the task of which was to prepare recommendations arising from the papers and subsequent discussions, was considered advisable by the persons attending the Symposium. The following recommendations were made by the working group, approved by the Salmon and Trout Committee and the Council, viz.:—

(a) That member countries pay special attention to the effects of predation on stocks of salmon and sea trout and that fishery workers should seek the co-operation of other scientists (e.g., ornithologists) and of others (e.g., hunters, anglers, and other sportsmen), who may be able to collect information relevant to the subject; and further that special investigations should be made into techniques of tagging suitable for the assessment of the intensity of predation.

(b) Member countries should, in the first instance, discuss this by correspondence with a view to organizing some tests in 1959.

(c) That a bibliography of tagging and marking be prepared to include references to sources of unpublished data as well as to published papers and that each country be asked to give a short introductory commentary on the bibliography supplied by it.

(d) That all member countries should carry out experiments to determine the comparative value of various types of tags and methods of tagging, and that in particular, as part of this programme, teams from different countries should participate in joint tagging programmes as a test of different techniques.

(e) That as all aspects of the biology of salmon and sea trout are in need of further investigation all member countries are urged to undertake studies on production, mortality, and fishing effort, with a view to the assessment of the population dynamics of the stocks of these species.

(f) That the Salmon and Trout Committee should establish a working group to consider the problems of salmon and sea trout in the Baltic.

(g) That the working party on salmon in the Baltic meet, if possible, in Sweden in March 1959 to further their consultations.

(h) The Salmon and Trout Committee wish to report that they have benefited very greatly from the presence among them of the Canadian Observer and wish to express their appreciation; they trust that similar co-operation will be possible at future meetings of the Committee.

G. Nikolsky

I. TAGGING METHODS

I. (1)

Short Report on Internal Tagging of Salmon Parr

By

ARNE LINDROTH

It is extremely important that tagged fish are representative of the population. This condition may be conflicting with other qualities required in the tags connected with facility in recovery.

External tags of different design are the most common type and the only type to use if recoveries are expected from market landings or sport fishermen. The external tag, however, may be suspected to hamper the fish, to make it more easily detected by predators, or caught in even wide-meshed gears, in short, to influence mortality.

A comparison between the external tag, extensively and successfully used by the Migratory Fish Committee in Sweden, and some other tags devoid of the possible disadvantages mentioned seemed, therefore, desirable.

Internal tags have been used for many species of fish as body cavity tags for halibut, herring and others, and as skin tags for perch. The first of this type was selected for internal tagging of salmon parr.

The tag is made of stainless steel $12 \times 3 \times 1$ mm with individual numbers punched.

Tagging is performed by means of a special apparatus best described as a modified grasshopper ovipositor. The tag is inserted in the body cavity between a knife opening the body wall and a small spring. Tagging costs are low and tagging speed considerable, up to 250 fish per hour with individual measuring and weighing, more than twice as many without weighing. This applies to anaesthetized fish.

On careful tagging no shedding of tags take place, except when ripe male parr are handled.

The quality of the tag is important in so far as sharp edges are to be avoided lest the tag should move into the body and damage the fish.

For recapture it is essential to rely upon fishing

centres where many internally tagged salmon can be expected so that installation of tag detectors is worth while. We have decided upon an X-ray technique which has rendered good service.

Nearly 20,000 salmon parr or smolts were tagged in the years 1952–1955 in co-operation with the Migratory Fish Committee. By the X-ray technique 175 tags have been recovered from two fishing stations in Indalsälven from 1954 to 1957. Moreover, 27 tags have been incidentally recovered from river and sea.

The technical and biological results will be discussed in detail in a coming report. The recaptures seem to be quite comparable to river recovery of external tags; closer examination of the material will be necessary in order to decide whether significant differences exist.

In passing, one item may be mentioned here. Of 11,450 parr and smolts tagged in the autumn of 1952 and the spring of 1953 and believed to be included in the smolt migration of 1953, 67 recoveries were made in 1954 by examination of about 1,600 grilse and 33 in 1955 by examination of about 900 salmon.

These figures imply a total smolt migration from river Indalsälven in 1953 of about 270,000 and 310,000 respectively, two figures in remarkably good agreement. The figure arrived at is in fairly good agreement but lower than that previously estimated, upon which the conservation programme for this particular river is founded.

References

- Lindroth, A., 1953. "Internal tagging of salmon smolt". Rep. Inst. Freshw. Res. Drottningholm, 34: 49–57.
— 1955. "Internal tagging of salmon smolt. Method of recapture. Returns 1954". Ibid., 36: 120–25.

I. (2)

Salmon Smolt Tagging Experiments at Invergarry Salmon Hatchery

By

D. H. MILLS

Introduction

In September 1955 preliminary tests to determine the efficiency of various types of tag was carried out on salmon parr in the ponds of the salmon hatchery at Invergarry (Inverness-shire, Scotland). The tags used were:—

- (i) The Lea hydrostatic tag, 3.0 cm long and 4.0 mm in diameter.
- (ii) Plastic tubing 5.0 mm long and 2.0 mm in diameter.
- (iii) A plastic disk approximately 5.0 mm in diameter.
- (iv) A celluloid square approximately 5.0 mm wide.
- (v) Silver wire, 0.0136 in. in diameter, twisted to form a small loop.

The tags were attached to the fish by soft, annealed silver wire, 0.0136 in. in diameter, threaded through the dorsal musculature slightly anterior to the base of the dorsal fin by means of a hypodermic needle 0.9 mm in diameter.

In February 1956 the fish were examined and the results showed that the proportion of fish still carrying a tag was highest in those with the lightest type such as the silver wire. It was also noticed that the wound caused by the insertion of the needle at the time of attaching the tag had healed or was only slight in those fish bearing the lighter marks but was more severe in fish with a heavier tag such as the small hydrostatic.

A more detailed tagging experiment was carried out on 400 two year-old smolts in 1957 and 1958, and it is the results of this experiment which are described in detail.

Method

On 7. May 1957, five batches, each of 40 fish, were tagged, each batch receiving a different tag. The tags used were:—

- (i) The Lea hydrostatic tag, 3.0 cm long and 4.0 mm in diameter.
- (ii) A small numbered silver plate or label 9.0 mm long and 3.0 mm wide.
- (iii) A small black button or disk 4.5 mm in diameter.
- (iv) Yellow plastic tubing 5.0 mm long and 2.0 mm in diameter.
- (v) Silver wire, 0.0136 in. in diameter, twisted to form a small loop.

The tags were attached to the fish as in the previous experiment. Length measurements were made and scale samples were taken from 20 % of the tagged fish, and a similar proportion of 200 untagged fish, used as controls, was also measured and scaled.

The 400 fish were kept together in a painted, circular concrete pond with a constant supply of running water. The fish spent the period 7. May to 30. September 1957 in a pond approximately 35 feet in diameter filled with water to an average depth of two feet nine inches and from then until the end of the experiment they were kept in a pond 20 feet in diameter with water to an average depth of 18 inches. Mean monthly temperatures during this period were as follows:—

	1957	°C
May.....	14.2	
June.....	18.6	
July.....	17.5	
August.....	18.1	
September.....	13.6	
October.....	9.7	
November.....	5.3	
December.....	4.7	
	1958	
January.....	3.3	
February.....	2.5	

The fish were fed on finely chopped liver two or three times a day depending on weather conditions.

Table 1. Numbers of fish retaining various types of tag (Percentages in parentheses)

Date	Period since tagging (days)	Numbers retaining tags					Total
		Hydrostatic	Silver plate	Black button	Yellow tube	Silver wire	
31/7-57.....	85	14 (35.0)	25 (62.5)	30 (75.0)	34 (85.0)	37 (92.5)	140
18/9-57.....	133	8 (20.0)	18 (45.0)	28 (60.0)	30 (75.0)	31 (77.5)	115
26/2-58.....	294	4 (10.0)	13 (32.5)	17 (42.5)	26 (65.0)	28 (70.0)	88

Table 2. Condition of tagging wounds

Date	Condition of wound	Percentage of tagged fish carrying				
		Hydrostatic	Silver plate	Black button	Yellow tube	Silver wire
31/7-57.....	Healed	2.5	22.5	30.0	30.0	30.0
18/9-57.....		12.5	25.0	25.7	45.0	50.0
26/2-58.....		2.5	7.5	12.5	32.5	57.5
31/7-57.....	Slight	15.0	25.0	27.5	37.5	40.0
18/9-57.....		5.0	12.5	21.4	25.0	12.5
26/2-58.....		5.0	10.0	20.0	27.5	10.0
31/7-57.....	Severe	17.5	15.0	17.5	17.5	22.5
18/9-57.....		2.5	7.5	12.9	5.0	10.0
26/2-58.....		2.5	15.0	10.0	5.0	2.5
31/7-57.....	Pulled out	65.0	37.5	25.0	15.0	7.5
18/9-57.....		80.0	55.0	40.0	25.0	22.5
26/2-58.....		90.0	67.5	57.5	35.0	30.0

Table 3. Growth of tagged and untagged fish

Date	Tagged			Untagged		
	Number in batch	Mean length (cm)	Mean increment (cm)	Number in batch	Mean length (cm)	Mean increment (cm)
7/5-57.....	40	16.3	—	40	16.1	—
31/7-57.....	32	18.2	1.9	40	17.5	1.4
18/9-57.....	30	21.3	3.1	40	21.2	3.7
26/2-58.....	28	23.9	2.6	40	23.5	2.3
			7.6			7.4

Results

The fish were examined on 31. July and 18. September 1957, and on 26. February 1958. The results of these examinations are given in Table 1.

At each inspection a note was made as to whether the wound caused by the insertion of the needle had healed, was slight or severe. It will be seen from the results summarized in Table 2 that the percentage in which the wound had healed or was slight was greater in the fish carrying the lightest tag.

It will be noticed that in the case of the silver wire the percentage in which the wound healed increased steadily at each inspection, this was also true of the yellow telcothene tubing at the first two inspections but not at the last. Those carrying the black button showed as rapid healing as the yellow

tube and silver wire at the first examination but after that there was a drop in the percentage healing which suggests that some of the wounds that were healing had re-opened while in others the marks had pulled out. The first two examinations showed an increase in the proportion with healed wounds in those with the silver plate but this trend was markedly reversed by February. In the case of the fish carrying the hydrostatic tag the percentage in which healing occurred was very small and as 90% of the marks had pulled out by the last examination this cannot be considered a very satisfactory tag for this class of fish.

There was little difference in the rate of growth of the tagged and untagged fish as can be seen from Table 3.

Conclusions

Although the number of fish used in the experiment was small it is evident that the two most satisfactory tags are the silver wire and the plastic telcothene tubing. The netting of the fish for examination caused some of the tags to be pulled out, this was especially true of the hydrostatic, silver plate and black button which became caught in the mesh of the net. The effect of the net, however, is perhaps similar to weed conditions in a river and Smith (1957) observed that the bridle type attachment of the hydrostatic tag he used on brook trout became fouled on aquatic vegetation. The weight of the tag and its movement in the water as the fish swims must also have some effect on the healing of the wound and a heavier tag seems more likely to keep a wound open than a lighter one.

The brightly coloured tags such as the yellow and blue hydrostatic and silver plate are very conspicuous in the water and are liable to attract the attention

of neighbouring fish. Smith (1957) noticed that trout struck at the hydrostatic tags carried by other individuals.

It can be concluded that light inconspicuous tags appear to be the most satisfactory for fish of the size of smolts. Though tags made of plain silver wire proved to be the most satisfactory in these tests, there was little to choose between the results from these tags and those made up from plastic tubing. The latter is available in a range of colours so that the colour pattern of the tag can be varied widely; so allowing different batches of fish to be tagged distinctively.

Reference

- Smith, M. W., 1957. "Lea's hydrostatic tag on brook trout and Atlantic salmon smolts". *Canadian Fish Culturist*, 20: 39-44.
-

I. (3)

The Use of Radioactive Calcium (Ca^{45}) for Marking Young Salmon

By

N. P. RUDAKOV

Introduction

The use of radio isotopes for fish marking assists in solving some urgent problems of fish culture and at the same time allows us to investigate more profoundly the principles of mineral exchange in fish.

Marking fish by means of radio isotopes has many advantages over mechanical marking methods, one of the most important advantages being the possibility of marking fish of different species and ages on a large scale.

For some years many scientific establishments in the USSR have been working out methods of fish marking by means of radio isotopes. However, in spite of the results achieved, many questions still need further consideration. In particular, the efficiency of marking fish of different species and ages has been studied, as well as the dosage of the isotopes applied (Karzinkin, 1955).

Some new data on this question, obtained mainly for trout, have been summarized in the present paper. The aim of the investigations was: (1) to define the principles of accumulation of different doses of radioactive calcium by fish of different ages and weights; (2) to clear up the question of Ca^{45} distribution in fish organs and tissues.

In our previous experiments analogous investigations have been carried out on carp fingerlings (Rudakov, 1957).

Material and Method

Fry and yearlings of *Salmo gairdnerii* Richardson were used in our investigations, which were carried out in tanks.

For marking and determining the degree of absorption of minerals from the environment, the fish were placed in radioactive solutions of $\text{Ca}^{45}\text{Cl}_2$ of different activity. After a certain time some of the fish (or their separate organs and tissues) were tested for radioactivity. The rest of the fish were transferred into a tank with water which was renewed from time to time to determine the decline of radioactivity. The presence of radio isotopes in fish or in separate organs and tissues was determined at fixed intervals.

The determination of radioactivity has been carried out in ash by methods used in radiometrics. For comparison the activity of the solutions in which the fish had been marked, was also determined. The total amount of calcium in solutions was trilonometrically determined.

Absorption of Ca^{45} by Trout Fry and Fingerlings of Different Weights

First of all we investigated the rate of absorption of Ca^{45} by trout fry and fingerlings weighing 0.079 g, 0.987 g, and 4.7 g, which were placed for 1–6 hours in $\text{Ca}^{45}\text{Cl}_2$ solutions of different activity: 32.4 $\mu\text{C/l}$, 324.3 $\mu\text{C/l}$, and 1.1 m C/l respectively. The tests were carried out at 14–16° C.

During the first hour the fry and fingerlings accumulate a considerable amount of Ca^{45} ($2.00 \cdot 10^{-5}$ – $50.09 \cdot 10^{-5}$ μg for 1 g of ash). When keeping the fish in the solutions for a longer period their radioactivity increases rapidly; during the first two hours it becomes approximately twice as much, then the absorption rate of Ca^{45} slows down. In a period of six hours the activity of the fish proved to be only four times more

than that of the fish kept in the solution for one hour (Table 1).

The most intensive absorption takes place in solutions of maximum specific activity. Although the activity of solutions is 33 times higher, the absorption in the highest concentration increases only 10 times. It is worth noticing that the absorption increases almost in proportion to the increase of the weight ratio

$$\frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}}$$

With age, the ability of fry and fingerlings to accumulate radioactive calcium diminishes.

Table 1. Absorption of Ca^{45} and the total calcium by trout fry and fingerlings of different weights and ages from solutions with activity of $32.4 \mu\text{C/l}$, $324.3 \mu\text{C/l}$, and 1.1mC/l . Average for 10 fish

($\omega = 0.165$; $k = 0.54$; $q = 1.091$; $S = 0.918^1$)

Weight of fish g	Time of marking in hours	$32.4 \mu\text{C/l}; \frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}} = 3.85 \cdot 10^{-8}$			$324.3 \mu\text{C/l}; \frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}} = 21.33 \cdot 10^{-8}$			$1.1 \text{mC/l}; \frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}} = 30.47 \cdot 10^{-8}$		
		Ca^{45} in μg per 1 g of ash	q	Total Ca in mg per 1 g of ash	Ca^{45} in μg per 1 g of ash	q	Total Ca in mg per 1 g of ash	Ca^{45} in μg per 1 g of ash	q	Total Ca in mg per 1 g of ash
0.079	1	$4.69 \cdot 10^{-5}$	27.61	1.2140	$28.09 \cdot 10^{-5}$	16.55	1.3240	$50.09 \cdot 10^{-5}$	8.85	1.5230
0.978		$3.68 \cdot 10^{-5}$	21.72	0.9557	$20.68 \cdot 10^{-5}$	12.19	0.9750	$33.08 \cdot 10^{-5}$	5.85	1.0062
4.7		$2.00 \cdot 10^{-5}$	11.77	0.5177	$12.05 \cdot 10^{-5}$	7.10	0.5678	$19.10 \cdot 10^{-5}$	3.38	0.5806
0.079	2	$8.43 \cdot 10^{-5}$	49.66	2.1850	$53.39 \cdot 10^{-5}$	31.46	2.5170	$90.16 \cdot 10^{-5}$	15.93	2.7400
0.978		$6.67 \cdot 10^{-5}$	39.30	1.7300	$37.96 \cdot 10^{-5}$	22.38	1.7900	$59.50 \cdot 10^{-5}$	10.52	1.8080
4.7		$3.80 \cdot 10^{-5}$	22.36	0.9837	$21.81 \cdot 10^{-5}$	12.84	1.0280	$34.62 \cdot 10^{-5}$	6.12	1.0530
0.079	6	$19.69 \cdot 10^{-5}$	116.00	5.1050	$120.83 \cdot 10^{-5}$	71.19	5.6960	$210.38 \cdot 10^{-5}$	37.18	6.3950
0.978		$15.11 \cdot 10^{-5}$	89.04	3.9180	$87.08 \cdot 10^{-5}$	51.30	4.1040	$135.61 \cdot 10^{-5}$	23.96	4.1210
4.7		$8.58 \cdot 10^{-5}$	50.59	2.2260	$50.03 \cdot 10^{-5}$	29.47	2.3580	$78.45 \cdot 10^{-5}$	13.87	2.3840

¹) Here and elsewhere in tables:— ω = correction for geometry

k = coefficient of absorption of β radiation in the counter window and in the air space in front of it

q = coefficient of inverse dispersion

S = coefficient of self-absorption of β radiation

The comparison of Ca^{45} absorption between carp and trout fry and fingerlings of the same weight showed that trout absorb radioactive calcium 1.3–1.5 times more intensively than the carp.

The total absorption of calcium by fry and fingerlings for different periods was calculated according to the data of Ca^{45} distribution between the fish and the environment (q). Calculations have been carried out when the concentration of calcium in the medium was: 4.4, 8.0, and 17.2 mg%. One ml of $\text{Ca}^{45}\text{Cl}_2$ solution, with the activity of $32.4 \mu\text{C/l}$, gave by using our method of measuring $7.2 \cdot 10^4$ impulses per minute.

Unlike carp, the quantity of calcium absorbed by trout fry and fingerlings depends mainly on the total concentration of this element in the environment. The maximum amount of calcium in fry and fingerlings of equal weight accumulate while they are kept in concentrated solutions. With the increase in weight of the fish the rate of absorption of the total calcium declines 1.2–3.0 times (Table 1).

As seen from the results of our experiments, trout absorb a considerable amount of calcium from the environment. In re-calculating the amount for fish weighing about 5.0 g it will come to 0.5 mg in six hours. A quantity of calcium such as this has undoubtedly a definite significance in the total calcium balance of trout. It should be noted that the relative rate of calcium accumulation is higher when the concentrations of calcium in solutions are low, as the coefficient (q) in this case increases. In other words, relative absorption of calcium from weak solutions is higher than from concentrated ones. This character-

istic of calcium absorption by fish enables us to assume adsorption to be the first stage of this process.

Finally, it is necessary to point out that the high value of the distribution coefficient (q), even when the concentration of calcium in the medium is 172 mg/l, serves as proof of great accumulating ability of trout with regard to calcium.

After the fish are transferred to pond water, which is free of Ca^{45} , their radioactivity diminishes remarkably. A more rapid fall is observed in the smallest fry and fingerlings marked when the solutions are most active. The decline of radioactivity during the first hour after marking continues at the highest rate, and then decreases. The decrease in the fall is also observed when the weight of the fish increases (Table 2).

At the same time it should be noted that in all variants of the experiment a more rapid fall of radioactivity was found in fish which had previously been placed in radioactive solutions for six hours.

An increased quantity of calcium in fish was observed immediately after they had been taken out of the solutions; this is undoubtedly connected with rapid absorption of calcium by the fish tissues. This process continues more intensively when the fish are kept in solutions of maximum activity for a longer period. After the fish are transferred to water which is free from Ca^{45} , a rapid loss of calcium, absorbed above the limit of saturation is noted. The loss of calcium depends solely on the degree of absorption, which is therefore, the highest in fish kept for long periods in solutions with maximum activity. However, the quantity of radioactive calcium left in the fish in this case appears to be the highest.

Table 2. The change in the content of radioactive and total calcium in trout fry and fingerlings after transferring them into water free of radioactivity

($\omega = 0.165$; $k = 0.54$). Average for 10 fish

Weight of fish, g	Time of marking in hours	Period of washing off in hours	32.4 $\mu\text{C/l}$		324.3 $\mu\text{C/l}$		1.1 mC/l	
			Ca ⁴⁵ in μg per 1 g of ash	Total Ca in mg per 1 g of ash	Ca ⁴⁵ in μg per 1 g of ash	Total Ca in mg per 1 g of ash	Ca ⁴⁵ in μg per 1 g of ash	Total Ca in mg per 1 g of ash
0.079	1	1	$3.92 \cdot 10^{-5}$	1.0160	$21.87 \cdot 10^{-5}$	1.0300	$35.03 \cdot 10^{-5}$	1.0650
		6	$3.58 \cdot 10^{-5}$	0.9272	$18.74 \cdot 10^{-5}$	0.8833	$27.65 \cdot 10^{-5}$	0.8405
		12	$3.41 \cdot 10^{-5}$	0.8828	$16.92 \cdot 10^{-5}$	0.7979	$24.36 \cdot 10^{-5}$	0.7404
		24	$3.34 \cdot 10^{-5}$	0.8664	$16.54 \cdot 10^{-5}$	0.7794	$23.85 \cdot 10^{-5}$	0.7249
0.987		1	$3.16 \cdot 10^{-5}$	0.8191	$17.34 \cdot 10^{-5}$	0.8172	$24.46 \cdot 10^{-5}$	0.7435
		6	$2.98 \cdot 10^{-5}$	0.7716	$15.17 \cdot 10^{-5}$	0.7152	$21.21 \cdot 10^{-5}$	0.6448
		12	$2.89 \cdot 10^{-5}$	0.7484	$14.29 \cdot 10^{-5}$	0.6736	$20.18 \cdot 10^{-5}$	0.6132
		24	$2.83 \cdot 10^{-5}$	0.7347	$14.07 \cdot 10^{-5}$	0.6630	$20.03 \cdot 10^{-5}$	0.6088
4.7		1	$2.07 \cdot 10^{-5}$	0.5368	$9.82 \cdot 10^{-5}$	0.4629	$15.92 \cdot 10^{-5}$	0.4838
		6	$1.95 \cdot 10^{-5}$	0.5066	$9.13 \cdot 10^{-5}$	0.4303	$14.09 \cdot 10^{-5}$	0.4284
		12	$1.88 \cdot 10^{-5}$	0.4871	$8.72 \cdot 10^{-5}$	0.4108	$13.45 \cdot 10^{-5}$	0.4088
		24	$1.85 \cdot 10^{-5}$	0.4804	$8.65 \cdot 10^{-5}$	0.4077	$13.34 \cdot 10^{-5}$	0.4055
0.079	2	1	$7.10 \cdot 10^{-5}$	1.8320	$37.02 \cdot 10^{-5}$	1.7450	$64.15 \cdot 10^{-5}$	1.9050
		6	$6.14 \cdot 10^{-5}$	1.5930	$29.16 \cdot 10^{-5}$	1.3740	$51.12 \cdot 10^{-5}$	1.5530
		12	$5.30 \cdot 10^{-5}$	1.3720	$26.01 \cdot 10^{-5}$	1.2260	$40.39 \cdot 10^{-5}$	1.2200
		24	$4.96 \cdot 10^{-5}$	1.2850	$25.80 \cdot 10^{-5}$	1.2160	$38.16 \cdot 10^{-5}$	1.1600
0.987		1	$5.57 \cdot 10^{-5}$	1.4430	$31.54 \cdot 10^{-5}$	1.4880	$42.81 \cdot 10^{-5}$	1.3010
		6	$5.03 \cdot 10^{-5}$	1.3030	$25.57 \cdot 10^{-5}$	1.2050	$35.83 \cdot 10^{-5}$	1.0890
		12	$4.61 \cdot 10^{-5}$	1.1590	$24.40 \cdot 10^{-5}$	1.1500	$32.36 \cdot 10^{-5}$	0.9835
		24	$4.30 \cdot 10^{-5}$	1.1140	$23.12 \cdot 10^{-5}$	1.0900	$30.73 \cdot 10^{-5}$	0.9340
4.7		1	$3.64 \cdot 10^{-5}$	0.9426	$17.82 \cdot 10^{-5}$	1.8403	$26.19 \cdot 10^{-5}$	0.8145
		6	$3.42 \cdot 10^{-5}$	0.8853	$15.93 \cdot 10^{-5}$	0.7509	$23.20 \cdot 10^{-5}$	0.7049
		12	$3.29 \cdot 10^{-5}$	0.8519	$15.11 \cdot 10^{-5}$	0.7120	$20.67 \cdot 10^{-5}$	0.6285
		24	$3.22 \cdot 10^{-5}$	0.8354	$14.90 \cdot 10^{-5}$	0.7025	$19.34 \cdot 10^{-5}$	0.5889
0.079	6	1	$14.14 \cdot 10^{-5}$	3.6640	$81.53 \cdot 10^{-5}$	3.7720	$130.40 \cdot 10^{-5}$	3.9630
		6	$10.63 \cdot 10^{-5}$	2.7550	$58.59 \cdot 10^{-5}$	2.7620	$92.90 \cdot 10^{-5}$	2.8230
		12	$8.80 \cdot 10^{-5}$	2.2810	$46.30 \cdot 10^{-5}$	2.1830	$74.44 \cdot 10^{-5}$	2.2620
		24	$8.39 \cdot 10^{-5}$	2.1770	$39.49 \cdot 10^{-5}$	1.8610	$61.17 \cdot 10^{-5}$	1.8600
0.987		1	$8.00 \cdot 10^{-5}$	2.0740	$58.08 \cdot 10^{-5}$	2.7370	$96.82 \cdot 10^{-5}$	2.5830
		6	$7.02 \cdot 10^{-5}$	1.8210	$45.93 \cdot 10^{-5}$	2.1650	$63.93 \cdot 10^{-5}$	1.9430
		12	$6.42 \cdot 10^{-5}$	1.6640	$38.42 \cdot 10^{-5}$	1.8110	$50.91 \cdot 10^{-5}$	1.5470
		24	$6.12 \cdot 10^{-5}$	1.5850	$33.87 \cdot 10^{-5}$	1.5960	$45.19 \cdot 10^{-5}$	1.3730
4.7		1	$6.75 \cdot 10^{-5}$	1.7490	$33.10 \cdot 10^{-5}$	1.5600	$53.02 \cdot 10^{-5}$	1.6120
		6	$5.29 \cdot 10^{-5}$	1.3720	$26.10 \cdot 10^{-5}$	1.2300	$39.11 \cdot 10^{-5}$	1.1890
		12	$4.30 \cdot 10^{-5}$	1.1160	$21.74 \cdot 10^{-5}$	1.0240	$30.43 \cdot 10^{-5}$	0.9249
		24	$4.06 \cdot 10^{-5}$	1.0530	$19.94 \cdot 10^{-5}$	0.9396	$28.89 \cdot 10^{-5}$	0.8782

In accordance with this a change in content of total calcium in the fish takes place (Table 2). Thus, one would think that with regard to trout marking it is advantageous to use solutions with the highest content of radioactive calcium. However, as mentioned above, the value of Ca⁴⁵ absorption in trout fry and fingerlings depends not only on the absolute content of the radio isotope, but also on the ratio $\frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}}$ in solution. This enables us to suggest that Ca⁴⁵ absorption is only a portion of the total absorption of this element by the fish.

At the same time the total quantity of calcium absorbed by fish from the environment increases in concentrated solutions. In accordance with this one can

expect to find the greatest accumulation of radioactive calcium when placing the fish in solutions with the greatest weight ratio $\frac{\text{Ca}^{45}}{\text{Ca}^{40} + \text{Ca}^{45}}$. Yet, as it was

shown in our previous experiments, the optimum absorption of the trout tissues occurs when the total concentration of calcium in the medium is 200–220 mg/l. When the concentration is higher there is hardly any increase in absorption. Thus, while marking trout with Ca⁴⁵ both the activity of the solution and the total content of calcium must be taken into consideration, and must not exceed the value given above. This value is likely to be near optimum, as it provides for the greatest accumulation of calcium in the tissues of growing fish.

Table 3. Data of the decrease in activity of trout after marking (solution $\text{Ca}^{45}\text{Cl}_2$ with an activity of 1.1 mC/l; weight of fish, 4.7 g)

Number of days after marking	Activity of whole fish imp./min. per 1 portion		Activity of all the bones values	
	Observed	Natural decay	Observed	Natural decay
1.....	116,470	116,470	94,500	94,500
2.....	83,200	—	89,860	—
5.....	71,530	—	88,110	—
10.....	66,340	111,400	79,620	90,360
20.....	59,110	106,400	74,060	86,260
30.....	56,240	101,600	70,900	82,410

For $\text{Ca}^{45}\text{Cl}_2$ preparations produced at present by the industry and containing up to 200 mg/ml of the carrier (Ca^{40}) the optimum concentration referred to above corresponds to the activity of 1.5–2.0 mC/l.

We consider the activity of the solution of 1.5 mC/l to be the most recommendable for trout marking and apparently for marking other young salmonid fish. In a solution like this the concentration of the carrier does not exceed 120–150 mg/l.

It should be noted that with regard to trout marking it will not advance matters to use either $\text{Ca}^{45}\text{Cl}_2$ which has lost a considerable part of its activity, or preparations containing an increased quantity of the carrier (more than 200 mg/ml). In solutions made of such preparations, the Ca^{45} absorption by fish decreases inversely with the increase of the total concentration of calcium.

The decrease of radioactivity in trout fingerlings has been studied for a longer period (30 days) on fish weighing 4.7 g and marked in a solution with an activity of 1.1 mC/l. The decrease of radioactivity in fish continues, on the whole, rapidly in the first days after marking, but declines gradually, although it continues rather quicker than could be expected in the case of solely natural decay of Ca^{45} (Table 3). This may be accounted for by the fact that the calcium present in trout organs and tissues is partially substituted by the calcium present in the environment.

The loss of radioactivity in the bones (Table 3) proceeds more slowly than that of the whole fish.

Even in this case, however, it continues quicker than the natural decay of Ca^{45} . These data show that in the osseous fish tissues the process of mineral restoration is carried on continuously.

Ca^{45} distribution in trout organs and tissues

The study of the distribution of radioactive calcium in organs and tissue has been carried out on trout yearlings weighing about 30 g. The fish were placed for six hours in a $\text{Ca}^{45}\text{Cl}_2$ solution with an activity of 50.0 $\mu\text{C/l}$. Every hour a number fish was taken out of the solution and analysed in order to determine the amount of Ca^{45} in the organs and tissues. The tests have been carried out at a temperature of 12–13°C, the total content of calcium in the medium being 46.13 mg/l.

The radioactive calcium is first and foremost accumulated on the external parts of the fish body, which are in direct contact with the solution (the gills, scales, fins, and skin). In internal organs, skeletal tissues, and vertebrae accumulation goes on at a somewhat slower rate. Furthermore, a general increase in Ca^{45} accumulation takes place in all organs and tissues. The rate of accumulation is particularly great during the first hours, then the increase in activity declines (Table 4).

Experiments showed that the gills of the fish investigated possess the greatest ability to accumulate Ca^{45} . This is in agreement with Krogh's view (Krogh, 1939) of the role played by gills in the direct ion exchange between fish and the environment. No doubt, this exchange takes place through the skin as well, as the latter accumulates a great quantity of Ca^{45} (Bogoyavlenskaya, 1955). The calcium absorbed through the skin and the gills is likely to be one of the sources by which the fish is provided with this element.

Finally, it should be noted that a similar Ca^{45} distribution in the organs and tissues is also observed in other fish (Bogoyavlenskaya, 1955; Kirpichnikov, Svetovidov, and Troshin, 1956 b).

In studying the decline of radioactivity in trout organs and tissues over six hours, it has been discovered

Table 4. Absorption of Ca^{45} by different trout organs and tissues in $\mu\text{g/l}$ of ash; average for 10 fish

($\omega = 0.165$; $k = 0.54$; $S = 0.949$)

Organs and tissues	Time the fish are kept in radioactive solutions (in hours)					
	1	2	3	4	5	6
Gills.....	$1.91 \cdot 10^{-6}$	$3.38 \cdot 10^{-6}$	$5.99 \cdot 10^{-6}$	$8.30 \cdot 10^{-6}$	$9.74 \cdot 10^{-6}$	$10.86 \cdot 10^{-6}$
Intestine.....	$1.06 \cdot 10^{-6}$	$1.76 \cdot 10^{-6}$	$2.26 \cdot 10^{-6}$	$2.33 \cdot 10^{-6}$	$2.40 \cdot 10^{-6}$	$2.49 \cdot 10^{-6}$
Liver.....	$0.61 \cdot 10^{-6}$	$1.12 \cdot 10^{-6}$	$1.47 \cdot 10^{-6}$	$1.65 \cdot 10^{-6}$	$1.73 \cdot 10^{-6}$	$1.80 \cdot 10^{-6}$
Spleen.....	$0.23 \cdot 10^{-6}$	$0.28 \cdot 10^{-6}$	$0.32 \cdot 10^{-6}$	$0.36 \cdot 10^{-6}$	$0.39 \cdot 10^{-6}$	$0.41 \cdot 10^{-6}$
Scale.....	$1.60 \cdot 10^{-6}$	$2.73 \cdot 10^{-6}$	$4.35 \cdot 10^{-6}$	$5.83 \cdot 10^{-6}$	$6.85 \cdot 10^{-6}$	$8.13 \cdot 10^{-6}$
Skin.....	$1.37 \cdot 10^{-6}$	$2.55 \cdot 10^{-6}$	$4.04 \cdot 10^{-6}$	$5.05 \cdot 10^{-6}$	$6.10 \cdot 10^{-6}$	$6.70 \cdot 10^{-6}$
Fins.....	$1.17 \cdot 10^{-6}$	$2.19 \cdot 10^{-6}$	$3.14 \cdot 10^{-6}$	$3.96 \cdot 10^{-6}$	$4.90 \cdot 10^{-6}$	$5.58 \cdot 10^{-6}$
Vertebrae.....	$0.76 \cdot 10^{-6}$	$0.9 \cdot 10^{-6}$	$0.98 \cdot 10^{-6}$	$1.05 \cdot 10^{-6}$	$1.12 \cdot 10^{-6}$	$1.18 \cdot 10^{-6}$
Skeletal muscles.....	$0.69 \cdot 10^{-6}$	$0.10 \cdot 10^{-6}$	$0.11 \cdot 10^{-6}$	$0.12 \cdot 10^{-6}$	$0.14 \cdot 10^{-6}$	$0.14 \cdot 10^{-6}$

Table 5. The decline of radioactivity ($\mu\text{g}/1\text{ g}$ of ash) in trout organs and tissues after transferring the fish into water free of Ca^{45}

Average for 10 fish ($\omega = 0.165$; $k = 0.54$; $S = 0.949$)

Organs and tissues	The time in hours of exposing the fish to water without radioactivity					
	1	2	3	4	5	6
Gills.....	$8.19 \cdot 10^{-6}$	$6.27 \cdot 10^{-6}$	$5.08 \cdot 10^{-6}$	$4.23 \cdot 10^{-6}$	$3.54 \cdot 10^{-6}$	$3.08 \cdot 10^{-6}$
Intestine.....	$1.72 \cdot 10^{-6}$	$1.24 \cdot 10^{-6}$	$0.91 \cdot 10^{-6}$	$0.64 \cdot 10^{-6}$	$0.49 \cdot 10^{-6}$	$0.35 \cdot 10^{-6}$
Liver.....	$1.16 \cdot 10^{-6}$	$0.83 \cdot 10^{-6}$	$0.59 \cdot 10^{-6}$	$0.44 \cdot 10^{-6}$	$0.31 \cdot 10^{-6}$	$0.26 \cdot 10^{-6}$
Spleen.....	$0.30 \cdot 10^{-6}$	$0.23 \cdot 10^{-6}$	$0.19 \cdot 10^{-6}$	$0.17 \cdot 10^{-6}$	$0.16 \cdot 10^{-6}$	$0.14 \cdot 10^{-6}$
Scales.....	$6.09 \cdot 10^{-6}$	$4.31 \cdot 10^{-6}$	$3.94 \cdot 10^{-6}$	$3.92 \cdot 10^{-6}$	$3.90 \cdot 10^{-6}$	$3.86 \cdot 10^{-6}$
Skin.....	$5.28 \cdot 10^{-6}$	$3.95 \cdot 10^{-6}$	$3.61 \cdot 10^{-6}$	$3.41 \cdot 10^{-6}$	$3.34 \cdot 10^{-6}$	$3.29 \cdot 10^{-6}$
Fins.....	$3.79 \cdot 10^{-6}$	$2.87 \cdot 10^{-6}$	$2.45 \cdot 10^{-6}$	$2.29 \cdot 10^{-6}$	$2.17 \cdot 10^{-6}$	$2.05 \cdot 10^{-6}$
Vertebrae.....	$1.18 \cdot 10^{-6}$	$1.15 \cdot 10^{-6}$	$1.14 \cdot 10^{-6}$	$1.13 \cdot 10^{-6}$	$1.12 \cdot 10^{-6}$	$1.11 \cdot 10^{-6}$
Skeletal muscles.....	$0.13 \cdot 10^{-6}$	$0.12 \cdot 10^{-6}$	$0.11 \cdot 10^{-6}$	$0.10 \cdot 10^{-6}$	$0.10 \cdot 10^{-6}$	$0.09 \cdot 10^{-6}$

that the main quantity of Ca^{45} leaves the body during the first hours after the fish have been transferred into water without radioactivity; in the gills, spleen, liver, and intestine the decline of radioactivity is at the highest rate. In six hours the activity of these organs diminishes 4–5 times. At the same time, the decline of radioactivity in the skin, scales, and fins goes on much more slowly. Ca^{45} recedes very slowly from the muscles and the vertebrae (Table 5).

In conclusion, it is necessary to note that in the USSR, besides marking fish in radioactive solutions, a method of marking by means of radioactive food is being studied (Danilshenko, 1957; Shekhanova, 1955). This method calls for much preparatory work and is less convenient. Besides, it has been stated that marking of small fry of bony fish by means of radioactive plankton is not effective (Kirpichnikov, *et al.*, 1956 a). Marking young sturgeon with radioactive *Oligochaeta* (*Enchytraeus albidus*) proved more efficient (Shekhanova, 1955).

Thus, only grown-up fry can be marked by means of radioactive food. Our method, which at present is being worked up, is devoid of the defects mentioned.

The application of radioactive isotopes in fishery investigations opens new prospects both for studying the question of fish returns and for solving many other important problems of fish management.

Summary

1. During one hour trout fry and fingerlings of different size (from 0.079 g up to 4.7 g) accumulate a considerable quantity of radioactive calcium from marking solutions. The radioactivity of fish kept in solutions for a longer period rapidly increases.

2. The accumulation of Ca^{45} in fish bodies depends both on the ratio of radioactive and stable isotopes and on the total concentration of calcium in the environment.

3. Comparing the data on Ca^{45} absorption between trout and carp fry and fingerlings of equal weight enabled us to state that trout absorbs Ca^{45} 1.3–1.5 times more intensively than the carp.

4. Unlike carp the absorption values in trout fry and fingerlings depends upon the concentration of this element in the environment. The ability of trout fry and fingerlings to accumulate calcium declines with age.

5. A considerable part of Ca^{45} is absorbed by fish organs and is washed away during the first hours. The most rapid decline of radioactivity (in 24 hours) is observed in fish kept in solutions with maximum activity for a long time.

6. For marking trout fry and fingerlings and apparently for other young salmonid fish it is advisable to use solutions with an activity of up to 1.5 mCi/l, the total content of calcium not exceeding 200.0 mg/l.

7. The decline in radioactivity of whole fish and their bones goes on more rapidly than the natural decay of Ca^{45} . This enables us to suggest that trout partially substitute the calcium lost from their organs and tissues by the uptake of calcium from the environment.

8. Ca^{45} is in the first place absorbed by the external parts of the body of the fish (the gills, scales, skin, and fins). In the internal organs, muscles, and bones, absorption takes place at a slower rate. When the fish is kept in radioactive solutions for a longer period a general increase in the accumulation of Ca^{45} in all organs and tissues is observed. During the period of exposal into water without radioactivity Ca^{45} is hardly ever lost from the osseous tissues of the fish.

It should be emphasized that all the experiments were carried out in the laboratory and no radioactive fish have been liberated to any natural waters. They constitute, therefore, no risk to human health.

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I. (4)

Some Notes on the Efficiency of two Types of Tag used for Tagging Sea-Trout Kelts in the River Dee, Aberdeenshire

By

W. M. SHEARER

Introduction

For approximately ten years sea-trout kelts have been tagged in the spawning tributaries of the River Dee. The sea trout average about 800 g in weight. The tag used in these experiments prior to 1954 consisted of a small red plastic plate, but as it was thought the percentage recapture of tagged fish was not as great as should be expected, in 1954, 1955 and 1956 a number of kelts were tagged with Lea's small hydrostatic tag, while others were tagged with the red tag.

The majority of the recaptures are made by commercial netmen in the River Dee estuary using bag-nets, jumper nets and fly nets, and by anglers. Each year there are two peak periods of recapture; in the spring when the sea-trout kelts are migrating downstream to the sea and in the summer when these fish are returning to fresh water to spawn.

1956). The average weight of the tag is 0.13 g and its average volume 0.07 ml.

(b) Hydrostatic tag

This tag measures 30 mm in length and carries the usual instructions to the captor inside. Its average weight is 0.45 g and its average volume 0.42 ml.

In 1954 both types of tag were attached to the fish by silver wire 0.0148 in. (0.04 cm) in diameter but in 1955 and 1956 stainless steel wire of the same diameter was used.

The method of attachment was the same for both types of tag. The wire was threaded through the fish immediately in front of the dorsal fin and then brought back over the outside of the fish and twisted on itself. Any spare wire was snipped off.

Results

These are given in detail in Table 1 and the main conclusions may be summarized as follows:—

(a) Red tag

Description of Tags

This tag is made of a red plastic material. It measures 18.0 mm long, 5.0 mm wide, and 0.5 mm thick. Both ends are rounded and in the centre at one end there is a small hole through which the wire attaching the tag to the fish passes. A number is engraved on one face and the other is marked "Fishery Board, Edinburgh" (tags used in 1954), or "Home Dept., Pitlochry" (tags used in 1955 and

- The proportion of kelts recaptured during their downstream migration to the sea was similar for both types of tag.
- A much greater proportion of the hydrostatic tags were removed on capture. Anglers and netmen had been asked to return all kelts to the water without removing the tag, but it

Table 1.

Year	Number of fish tagged		Percentage recapture of tagged kelts		Percentage of tagged kelts recaptured where tag removed		Percentage recapture of tagged clean fish	
	Red tag	Hydrostatic tag	Red tag	Hydrostatic tag	Red tag	Hydrostatic tag	Red tag	Hydrostatic tag
1954.....	240	169	7.1	6.5	0	36.4	13.8	4.7
1955.....	447	232	10.7	11.6	8.3	40.7	10.5	7.8
1956.....	1,064	346	13.1	13.3	10.1	28.3	23.5	14.2

would seem that the printed instructions within the Lea tag led some anglers and netsmen to forget this request.

- (c) Judged on the basis of recapture of clean fish, the red tag was more successful than the hydrostatic tag.

Discussion

Although the Lea hydrostatic tag is much larger than the red tag, the results do not show that it was more easily detected by the captors of tagged fish. In fact there is evidence for suggesting that the

size of the tag is a disadvantage. There is little difference between the percentage recapture of kelts tagged with the two types of tag but there is an appreciable difference between the percentage recapture of clean sea trout tagged with the two types of tag. It is suggested that the probable reason for this difference is that the hydrostatic tag becomes detached from the fish more readily than the red tag, possibly because of its greater weight and greater bulk. The latter would be particularly important in places where estuaries are commercially netted, as the larger tag would tend to be more easily caught and torn off in the meshes of a sweep-net.

I. (5)

A Review of the Efficiency of the Types of Tags used in Denmark for Salmon and Sea Trout, as shown by the Recaptures

By

JØRGEN DAHL

Introduction

From 1927 until now regular tagging experiments with salmonid fishes have been carried out in Denmark. The experiments have mostly included sea trout, but also a smaller number of salmon has been tagged. Nearly all sizes and life stages of the fish have been included in the investigations. During the period mentioned different types of tags and tagging procedures have been employed in order to find the tag best suited for getting the greatest number of recaptures.

In the following a summary of these experiments has been made in order to examine, to what degree the recaptures in the different experiments can be taken as a measure of the suitability of the tags concerned.

The Tag Types

In the experiments both individual and collective taggings have been undertaken. Altogether 9 types of tags have been employed, and different combinations of colour and wire were used. The tag types are listed in Tables 1 and 2. The button tags were fixed to the gill cover, the wired tags in all cases to the back of the fish, either in front of or below the dorsal fin. The silver safety pin was fastened to the back of the fish in front of the dorsal fin.

In order to clear up the longevity of the tags in the different experiments the total number of recaptures has been split up in recaptures from the first year, second year, and third year. This is the reason why the analyses do not include the years 1955, 1956, and 1957, where two new types of tags were taken into use, one for individual taggings, and one for collective taggings.

The weights of the different tags employed range from 35 to 523 mg, the heaviest tag being the silver safety pin. The two tags employed in the last 3 years weigh 85 and 32 mg respectively.

In some of the collective tagging experiments no

tags were used. Instead of that removal of fins in different combinations was undertaken. Fin removal has only been carried out on small fish: fingerlings, yearlings, and smolts. In some cases the adipose fin was removed by burning with an electric cautery, in other cases one or both of the pelvic and pectoral fins were removed by cutting.

Results

The results of the tagging experiments are summarized in Tables 1 and 2. The best results have been obtained with the tags on stainless steel wire and with the silver safety pin. The recaptures from these taggings range from 11.4% to 17.1%. The tags on nylon wire, as well black, braided nylon and monofil nylon, show very low recaptures. This result was expected, though, already when the taggings were undertaken, as it proved to be very difficult to get the nylon thread to hold the knots.

The button tag ("Rugela" type) fastened in the gill cover has been shown to be of almost no value. This may be caused either by an insufficient skill in the tagging procedure or by the unfittedness of the tag type. Only 2 "recaptures" have been obtained from 246 fish tagged with the "Rugela" button, both tags having been found hanging in the fishing gear and no fish present. Fishes have been caught having small, round dark scars in the gill cover, showing that they had been tagged with the button tag, but had lost it. Many of the fishes tagged in this experiment lost their tags even before they were liberated.

The weight of the tags has apparently not influenced the number of recaptures. Good as well as bad results have been obtained with tags of the same weight.

It might be expected beforehand that the colour of the tag would to a certain degree determine the facility of its detection, when the tagged fish are

Table 1. Taggings of sea

	Type of tag	Type of wire	Av. weight of tag (g)	Fingerlings		
				Number tagged	% rec. 1. year	% rec. 2. year
Individual taggings	Silver button ("Rugela")		0.286			
	Silver safety pin		0.523			
	Celluloid disk, red ("Rugela")	Stainless steel	0.035			
	Silver disk ("Rugela")	Silver	0.155			
	Waterproof paper ("Wolf")	Stainless steel	0.123			
	Nokatene, pale-blue	Black, braided nylon	0.111			
	—, —	Stainless steel	0.111			
	—, ultramarine	Black, braided nylon	0.107			
	—, —	Stainless steel	0.107			
	—, red	—	0.110			
	Celluloid, orange	Monofil nylon	0.082			
	—, —	Stainless steel	0.082			
Collective taggings	Glass beads of diff. colours	Silver	0.068			
	Burning of adipose fin			200		
	Clipping of diff. fins			433	0.2	

¹⁾ Only the tags found in the gear. ²⁾ 0.3 % recaptured twice. ³⁾ 3.4 % recaptured immediately after liberation and relib

Table 2. Taggings of sa

	Type of tag	Type of wire	Av. weight of tag (g)	Fingerlings			
				Number tagged	% rec. 1. year	% rec. 2. year	% rec. 3. year
Individual taggings	Silver safety pin						
	Celluloid, orange	Stainless steel	0.082				
Collective taggings	(No tag)	Silver					
	Glass beads of diff. colours	—	0.068				
	Burning of adipose fin			8,300			

handled by the fishermen. The analysis shows, however, that the colour of the tags does not influence the number of recaptures, the silver safety pin and the pale-blue Nokatene tag being just as easily detected as the red tags.

The tagging experiments undertaken by removal of different fins show very low recaptures. Whether this is due to some lethal effects of the tagging procedure to the small fish or the fin-clipped fish are not detected at recapture cannot be said with certainty. The latter explanation seems to be the more probable, as fin removals on fish in aquaria have shown that the fish does not suffer damage from the operation.

Influence of the Tagging Locality on the Recaptures

Although the number of recaptures seems to give a certain picture of the effectiveness and suitability of the tags used, one should be careful not to draw too far-reaching conclusions from these figures. Table 3 shows that the locality used for the tagging experiment greatly influences the number of recaptures. This means that in many cases the recaptures give a measure for the fishing intensity in a given area, rather than of the suitability of the tags used.

The table shows clearly that the number of recaptures is greater, when tagging experiments are undertaken in estuaries, or in streams debouching

mark 1927-1955

Yearlings			Smolts			Big fish				Total					
% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% recaptures	% rec. 1. year	% rec. 2. year	% rec. 3. year
			246	0.8							246	0.8	0.8 ¹⁾		
			176	8.0	1.7		75	18.7	6.7	1.3	251	14.7	11.2	3.2	0.3
			36	(5.6)			8	(37.5)			44	11.4	11.4		
			40								40				
			21	(4.8)			342	17.8			363	17.1	17.1		
			395	0.5			302	1.7			697	1.0	1.0		
			450	14.4	2.0		258	14.3			708	15.0 ²⁾	13.7	1.3	
			106	0.9			104				210	0.5	0.5		
			89								89				
			1,701	5.5	0.1		58	3.4			1,759	5.5 ³⁾	5.3	0.2	
			6,515	0.9	0.1	0.03					6,515	1.1	0.9	0.1	0.03
			1				1,592	14.9	1.1	0.06	1,593	16.1 ⁴⁾	14.9	1.1	0.06
			100	5.0	1.0						310	1.9	1.6	0.3	
	0.3	0.1									9,884	0.4		0.3	0.1
1.6			495	0.2	0.2	0.4					1,742	1.0	0.87	0.06	0.07

¹⁾ % recaptured twice, 0.03 % recaptured three times.

mark 1927-1955

Yearlings			Smolts			Big fish				Total						
% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% rec. 1. year	% rec. 2. year	% rec. 3. year	Number tagged	% recaptures	% rec. 1. year	% rec. 2. year	% rec. 3. year	% rec. 4. year
			244	5.3			70	1.4			314	4.5	4.5			
							36	(22.2)			36	(22.2)	(22.2)			
0.5			236	0.4							200	0.5	0.5	0.2		
											461	0.2				
											8,300	0.02				0.02

into estuaries, or when taggings are made in streams in which regular scientific investigations are carried out, for instance by means of electrical fishing. The number of recaptures is low when taggings are made in streams debouching into the open sea.

This also explains the remarkably low number of recaptures obtained with the red Nokatene tag on a stainless steel wire, which is recorded in Table 1. Judging from the experiences in other experiments, where tags on stainless steel wire have been used, we should expect a similar high percentage of recaptures with this tag. However, almost the whole lot of fish tagged with red Nokatene on stainless steel wire were liberated in the mouth of a stream debouching into the open sea.

The Longevity of the Tags

In all the tagging experiments the greatest number of recaptures have been made in the first year after the liberation of the tagged fish. In the second year only a few are recaptured, in the third year after the liberation even fewer. From this information the suitability of the tags is clearly shown. Only the tags on stainless steel and the silver safety pin show any considerable number of recaptures the second year (see Table 1).

However, also fish tagged with the orange celluloid tag on monofil nylon thread have been recaptured in both the second and the third years. It was mentioned above that it proved difficult to

Table 3. Tagging experiments with orange celluloid tags on stainless steel wire

Type of locality	Number tagged	% recapt.	% recapt. 1. year	% recapt. 2. year	% recapt. 3. year
Estuaries, and streams debouching into estuaries .	372	20.1	19.6	0.5	—
Streams debouching into the open sea	707	8.0	6.8	1.1	0.1
Streams regularly investigated by scientific electrical fishery	550	24.1	22.5	1.6	—

get the knots to hold in this type of thread. The figures in the table seem to show that a certain — though probably low — percentage of the tags have been tied satisfactorily, and that the suitability of this thread depends on the technique of tying the knots.

Conclusions

From the data recorded above the following conclusions may be drawn.

1. Neither the colour nor the weight of the tag seems to influence the number of recaptures.
2. Button tags ("Rugela" type) have proved to be

of no value as regards tagging experiments with salmonid fish.

3. There has not been found any difference in the suitability of the tags used for smolts and for big fish.
4. The locality chosen for the tagging experiment greatly influences the number of recaptures, so that these become an expression of the fishing intensity in a given area rather than of the suitability of the tag.
5. Collective taggings by means of removal of fins in different combinations are of very little value, probably because the fin-clipped fish are not detected by the fishermen.

I. (6)

The Efficiency of Various Types of Tags

By

A. SWAIN

Before any tagging work is undertaken the methods of catching the fish and handling them should be considered most carefully. The need to exercise the utmost care cannot be emphasized too strongly, and unless this precaution is taken, any type of tagging is worthless.

A large amount of the tagging work on salmon and sea trout carried out by the Ministry in recent years has been done on the River Coquet at Warkworth in Northumberland. Here, a wooden grid type trap was installed into one of the pools of a fish pass situated at the upper limit of the tidal water. This trap was constructed to catch descending smolts and kelts, the fish being collected for tagging in wooden boxes through which the river water flowed continuously. In the case of the smolts each fish was held in a specially made rubber block, the operation of tagging being carried out with the fish under water. No anaesthetics were used during any of the experiments.

As the reasons for tagging salmon and sea trout are numerous and varied, clearly it is difficult to produce a tag which would be ideal for all occasions. The main object of carrying out the tagging programme on the Coquet was to find out about movements of sea trout off the east coast of England. During the summer months sea trout are caught off the East Anglian coast, and as the rivers in that area do not contain migratory fish it was thought that they come down the coast from the more northerly rivers. As salmon smolts were caught on the trap at the same time these too were tagged in order to discover something about their movements. Consequently, as the commercial fishermen and rod-men would have to be relied upon to report many of the recaptured fish, an external tag was used throughout the experiments, no internal tagging being undertaken at all.

External tags have been used in a multitude of forms, shapes, and colours. They have been fixed to various parts of the fish's body and different modes of attachment have been employed. The external tag should have the advantage of being clearly visible to the captor but not so easily seen by predators. It should not interfere with the normal free swimming

of the fish, but at the same time it should be sufficiently firmly attached so as not to break away during the usual day to day activities of the fish. In the case of salmon and sea trout, the material from which the tag and its attachment are made must be capable of withstanding the effect of sea water for some years.

All the tags used on the Coquet salmon and sea trout were attached to the anterior end of the base of the dorsal fin. For the smolts, two kinds of materials were used. One was a small diamond-shaped silver plate, the other a small square Ivorine plate 40/1000 inch thick, Ivorine being a form of thick celluloid. In all cases, the attachment was by means of silver wire 0.015 inches in diameter. The wire passed through two holes in the tag and was inserted into the fish using a hypodermic needle. The two ends of the wire were twisted together to form a small loop. The silver and ivorine tags withstand the effect of sea water very satisfactorily but the silver wire tends to become brittle after a while. There is some improvement when the wire is annealed, but silver is not completely ideal for the purpose although it is much better than many other metals.

Salmon smolts were tagged during the 1952 to 1957 seasons. In 1952, some of the smolts were tagged with the silver tag, others were tagged with a blue ivorine tag. (Table 1 gives the numbers of smolts tagged, together with the corresponding recapture figures.)

Table 1. Recaptures of tagged salmon smolts, River Coquet, Warkworth

Year when tagged	Type of tag	Numbers tagged	Numbers recaptured	Percentage recaptured
1952	Darkened silver .	669	18	2.7
	Blue ivorine . . .	1,488	25	1.7
1953	Blue ivorine . . .	3,497	68	1.98
1954	Blue ivorine . . .	2,859	48	1.7
1955	Blue ivorine . . .	4,000	49	1.22
1956	Blue ivorine . . .	3,587	13	(To Date)
1957	Blue ivorine . . .	6,539	13	

One fish was caught in the pre-grilse stage off Norway, but the majority of the tagged salmon were caught after they had spent two years in the sea.

Quite a number were caught as grilse and a few were taken after spending three years at sea. A large proportion was netted off the north-east coast of England but a few were taken off the west coast of Scotland. Unlike the sea trout, no salmon were or are caught off East Anglia.

The percentage recaptures were higher than for sea-trout smolts although fewer salmon than sea trout are caught off the Northumberland coast. The relatively few fish tagged with the silver tag produced significantly better results than those tagged with ivory tags — between 1.22 and 1.98 per cent. for the ivory and 2.7 per cent. for the silver. Recaptures from the 1956 and 1957 tagging experiments are still being reported.

Sea-trout smolts were tagged in the Coquet during the seasons 1951 to 1957. In 1951 a small darkened silver plate tag was used, exactly the same as the ones used on the salmon smolts in 1952. In the following year, both the silver plate and a transparent colourless ivory tag were used, the ivory tags being much less expensive than the silver ones. In succeeding years a different coloured ivory tag of identical shape and size was used. Table 2 lists the numbers of sea-trout smolts tagged each year, together with the corresponding recapture figures.

Table 2. Recaptures of tagged sea-trout smolts, River Coquet, Warkworth

Year when tagged	Type of tag	Numbers tagged	Numbers recaptured	Percentage recaptured
1951	Darkened silver .	3,930	84	2.14
1952	Darkened silver .	2,503	40	1.6
	Transp. ivory .	5,000	63	1.26
1953	Red ivory	5,671	24	0.43
1954	Green ivory . . .	5,022	32	0.64
1955	Yellow ivory . .	6,031	8	0.013
1956	Grey ivory . . .	3,890	5	0.013
1957	Darkened silver .	2,995	11	0.37
	Grey ivory . . .	1,060	3	0.28
	Green ivory . . .	1,978	4	0.2
	Red ivory	566	1	0.18
	Mauve ivory . .	399	0	0
	Swedish type . .	317	0	0

A large proportion of the tagged sea-trout smolts caught in the post-smolt stage was netted off the Norfolk and Suffolk coasts, whereas during their second year they were mostly caught off the Northumberland coast or in the parent river.

It can be seen that the percentage of recaptures of fish tagged with the silver tag was higher than those tagged with the various coloured ivory ones. The χ^2 test was applied to the results and this showed that significantly better results were obtained with the silver tags. Of the ivory tags, the transparent variety, which was also colourless, was the most successful. The percentage recaptures of sea

trout tagged with the yellow ivory tags in 1955 and with grey ivory tags in 1956 were extremely low (0.013 per cent.). Yet the total weight of the sea trout catches in the Norfolk and East Suffolk River Board area during those two seasons was higher than those for each of the three previous seasons. Over 4000 lb weight were reported to have been caught in 1955 and over 3000 lb in 1956. In 1952, 1953, and 1954, the annual figure was less than 3000 lb. The total number of sea trout caught in the Northumberland and Tyneside River Board area was also higher in 1955 and 1956 than in 1951, 1953, and 1954. Over 13,000 were caught in 1955 and around 10,000 in 1952 and 1956. About half this number was reported as having been caught in 1953 and 1954.

It may be significant that the tags producing the lowest recapture percentages, that is, the yellow and grey ivory tags proved to be the most easily visible when they were attached to the smolts, and it is possible that these fish may have been subjected to heavier predation. On the other hand, the transparent colourless ivory tag was almost invisible in the water and the number of recaptures were much higher than those from the other coloured ivory tags.

In the 1957 season, the sea-trout smolts were tagged with various coloured ivory tags alternating with the silver ones, and again from the results so far received it would appear that the silver tag is the most satisfactory. A number of Swedish smolt tags kindly presented to the Ministry by Dr. Carlin were also used in 1957. These were fastened to the fish with a double wire attachment, but so far none of these tags has been returned.

Although the lighter coloured tags gave the most unsatisfactory returns for the sea trout, the pale blue ivory ones used on the salmon were also very conspicuous. Yet the percentage recaptures of salmon tagged between 1952 and 1955 were well over one per cent. and in most years nearer 2 per cent. It would appear that other factors might affect the tagged sea trout. The salmon, once it enters the sea, grows more quickly than the sea trout and in the deeper parts of the sea would encounter less weed and other obstacles, so that although the tag may become partly buried, the chances of it running foul of obstructions would be less. The sea trout, however, grows more slowly at sea than the salmon and is more coastal in its habits. Consequently, the tagged sea trout might be in danger of meeting various snags for a longer period of its life. Reports have been received from time to time of wounds near the dorsal fin and occasionally a piece of silver wire only has been found attached to the fish.

Table 3. Recaptures of tagged sea-trout kelts, River Coquet, Warkworth

Year	Number of kelts caught and tagged	Type of tag	Number recaptured	Percentages recaptured	Kelts tagged during previous season recaptured as kelts on trap
1952.....	659	Einar Lea	82	12.2	1
1953.....	872	— —	110	12.6	8
1954.....	1,021	— —	168	16.4	10
1955.....	1,342	— —	210	15.6	30
1956.....	75	— —	7	9.3	—
	Examined but not tagged				
1956.....	2,138	—	—	—	43
1957.....	439	—	—	—	2

In 1956 and 1957, in addition to the normal tagging, the left pelvic fin of each tagged smolt, both salmon and sea trout, was clipped and it is proposed to examine all kelts caught on the trap for signs of tagging and fin-clipping. Recently a few tagged salmon have been recaptured in the sea and it was reported that their pelvic fins were clipped, but only one instance of a clipped fin in the absence of a tag has been reported so far.

A large number of sea-trout kelts have also been tagged in the River Coquet. Between 1952 and 1957, 6,546 sea-trout kelts were caught and of that number 3,969 were tagged. On all occasions the Lea hydrostatic tag was used, at first the large type and later the smaller variety. The tag was attached to the base of the dorsal fin in the usual way by means of stainless steel wire. A monofilament nylon attachment was tried out on about 40 of the smaller kelts and 15 per cent. of these were recaptured — comparing favourably with the steel attachment.

Table 3 gives the numbers of kelts caught and tagged between 1952 and 1957 and the corresponding recapture data.

Apart from the 1956 season when only a few kelts were tagged the percentage recaptures varied from 12.2 to 16.4. Of the 75 kelts tagged in 1956 only 9.3 per cent. were recovered. Unlike the remainder which were tagged in the spring, those 75 were tagged during December.

Of the 3,969 kelts tagged at Warkworth, 94 were caught again on the trap as kelts for the second season running, but of all the 6,546 kelts examined only 23 were observed with the smolt tag attached. A large proportion of the sea-trout kelts were caught in the sea off the Northumberland coast during the four or five months following the tagging.

It has been mentioned that a number of the smolt tags become detached or embedded during the life of the fish. Similarly, about a dozen of the Lea tags have been recovered detached from the fish. Isolated Lea tags have been picked up on beaches

in Northumberland, Yorkshire, and Norfolk and on the Coquet River bank. One tag was recovered on the Friesian Islands. They were all picked up close to where netting operations are carried out.

It is interesting to record, however, that some of the tags have remained on the fish for quite long periods. For example, a transparent ivorine tag has been recovered from a sea trout after being attached to the fish for 3 years 4½ months, and a silver tag has been recovered after 3 years 3½ months. The longest period of all was exactly 4 years for a silver tag attached to a salmon smolt in April 1952 and recovered from the fish as a kelt in April 1956. The kelt was recaptured on the trap where it was first tagged as a smolt. The tag was clearly visible, the person carrying out the experiment recognizing the tag during the hours of darkness. The longest period for a Lea tag was 2 years 11 months. The tag was attached to the fish as a kelt in the first instance.

The Ministry has to rely to a large extent on recaptures from individual fishermen, both netmen and rod-men, so it is possible that returns may not be so complete as they might be from some large organization. For instance, certain wholesale fish dealers who handle the fish straight from the fishermen have returned many of the tags and have supplied much useful information.

To conclude, it appears from this account of the tagging, that with the existing system, a large number of smolts have to be tagged to produce a reasonable number of returns. Bulking the Coquet series of experiments together, so far over 39,000 sea-trout smolts were tagged to produce 275 recaptures and over 23,000 salmon smolts to produce 238 recaptures.

There must, of course, be a large natural mortality between the smolt stage and the adult, so clearly, considering all the other hazards, it is essential that a suitable tag should be used and the fish that have been tagged should be released undamaged and in the best of condition.

II. SMOLTIFICATION AND LIBERATION

II. (1)

The Effect of the Liberation of Sea-Trout Fry in the Gudenå Area, as shown by the Trout Catch in the Lower River and the Randers Fjord

By

KNUD LARSEN

Liberation of fry of salmon and sea trout in Danish streams was started about the beginning of this century, for example in the Gudenå and its tributaries in 1901 and 1902 and in the Mariager fjord tributaries in 1901. These and following liberations were carried out in the conviction, that the more fry liberated the better would be the catches in the future.

Not until 1919 was an attempt made to estimate the efficiency of the liberations carried out during earlier years in the above mentioned streams (Johansen and Løfting, 1919). For several reasons, however, the results should be taken with some reservation. In connexion with the estimation an essential source of error was the fact that the fishery statistics were being developed during the period 1901–1919. Of course this will easily give—and no doubt has given—a too optimistic picture of the value of the liberations.

Poulsen's illustration of the relation between liberation and catch of trout in the Gudenå and Randers fjord during the period 1913–1934 is essentially better supported. The main result was that, everything having been taken into consideration, it appeared impossible to point out any effect of the liberations at all, although they had amounted on the average to 535,000 fry per year from 1920 to 1934 besides a number of fingerlings, varying from 15,000 to 99,000 in the years 1913–1915 and 1921–1924. On the contrary, occasionally it was possible to observe a severe disagreement as to what could be expected in the years after a liberation and the actual catches (see Fig. 1).

We have few particulars until 1936 on the distribution of the trout fry within the Gudenå area. No doubt, it has occasionally been rather bad, and often the fry were liberated in places where liberation is inconceivable today, thus among others in the

main stream of the river, where there is deep water and consequently plenty of fry predators, such as perch, pike, and roach.

In 1936 the methods of liberation were altered. From this year and especially from the following one great care was taken to get the fry distributed as widely as possible within the whole area, giving preference to the small, swiftly running brooks, giving shelter to none or few fry predators ("Liberation *ad modum* Otterstrøm", cf. Otterstrøm, 1938; Larsen, 1945).

The number of trout fry liberated "*ad modum* Otterstrøm" in the Gudenå area since 1937 has on the average been approximately 450,000 per year or 85,000 less than in the previous 16 years. They are now distributed in 386 places of liberation, above as well as below the dam at the Tange hydroelectric power station, the dam being impassable to ascending salmon and sea trout.

The establishment of the power station dam across the main river at Tange in 1920 cut off the stock of salmon from their spawning grounds in the middle part of the river and in some tributaries above the dam, and in 1925 the salmon fishery in the river and the Randers fjord ceased. Also a part of the stock of sea trout had its spawning grounds in the cut off part of the river, and from 1925 the catch of sea trout in the river and in Randers fjord decreased abruptly. During the period 1913–1923 the mean catch was 4,235 kg. During the period 1924–1934 it dropped to only 2,295 kg, i.e., 54.2 per cent. of the original catch (Poulsen, 1935).

The liberations of sea-trout fry during the period mentioned thus have not been able to maintain the stock, let alone to increase the output of the fishery.

What has now been the effect of the liberations *ad modum* Otterstrøm carried out since 1937?

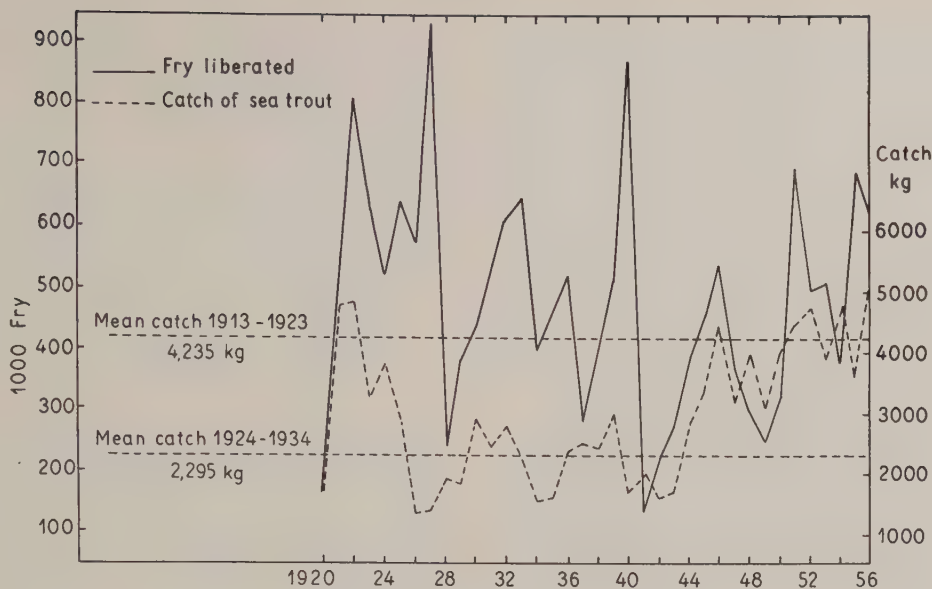


Figure 1.

According to the biology of the sea trout it would be expected that the catch of sea trout would increase in 1940 or 1941. On the contrary it decreased and an increase was not apparent until 1945–1946, from which time we find a clear and steady increase. From 1946 to 1956 the output has averaged 4,133 kg per year or practically the same as in the period prior to the establishment of the power station dam.

The increase that failed to appear in the first half of the 1940's could be explained by some inefficiency in the liberations, failing to develop a larger stock of catchable trout, and in this way calls attention to the somewhat doubtful value of the liberations.

However, this does not seem to be the case.

The decrease of the trout catch in the years 1940–1943 and the failure to increase in 1944 is not only known from the Gudenå and Randers fjord. You will find just the same decrease of the trout catch in the estuaries of West Jutland, although the catches normally fluctuate quite independently of the Gudenå catches, and you will find the same in the total catch of trout in fresh water all over the country. The chances, therefore, are that some overall factor—possibly more than one—has asserted itself during the short series of years in question.

An examination of the monthly catches of trout in the river Gudenå and Randers fjord makes it probable, that the main overall agent is to be found in the severe winters during the war. In the months April–December the catch was quite normal during this period, whereas the catch of the three first

months of these years was exceptionally small compared with the catch of the same months in “normal” years. Another factor limiting the catch may be difficulties during the war to obtain enough gear for the fishermen to cope with an increase in the number of fish.

Since 1950 the catch of sea trout in the Gudenå and Randers fjord has been fluctuating constantly around the mean catch prior to the establishment of the power dam at Tange.

Figure 1 above shows that the annual mean catch of trout in the Gudenå and Randers fjord increased with 1,265 kg and 1,838 kg during the periods 1941–1956 and 1946–1956, respectively. As the mean weight of the sea trout in this area is 2,664 kg (based on 1940 fish caught in 1956) the greater output in kilogrammes corresponds with an increase in catch of 475 and 690 trout respectively, per year in the two periods concerned. This means, that only 1.05–1.53 ‰ of the fry liberated are recaptured as adult fish in the river system. It is probable, that a proportionate increase in the catch has taken place outside the river area, along the east coast of Jutland as a result of the liberations, even if we have no certain information about this.

Thus, per 1000 fry liberated since 1937 in the Gudenå area we have captured 2–3 trout with a total weight of 5.3–8 kgs.

From this it is possible to decide whether the liberation has paid or not, if we know the first-hand price of sea trout.

According to “Fiskeriberetning for året 1957” p. 96

(the annual report on the Danish fisheries) the first-hand price per kg of sea trout was 4.88 kr. in 1957 and 5.26 kr. in 1956. Thus we can estimate a mean price of 5.00 kr. per kg, which means that the fishermen at the Gudenå and Randers fjord have had an annual mean income of 6,325 and 9,190 kr. during the periods 1941–1956 and 1946–1956, respectively, from the increase of the catch.

During the same periods the liberation has averaged 450,000 fry per year. Without greater error the price of the fry, including the distribution within the area of liberation, can be estimated to 15 kr. per thousand. That makes a total expense of 6,750 kr. per year.

From this it is evident, that the liberation *ad modum* Otterstrøm in the Gudenå area, judged by the local fishermen, has almost paid during the total period 1941–1956. During the last 11 years of the period, however, there has been an annual profit of about 2,500 kr. From the view of the sea-trout fishery as a whole (the local fishery, together with the coastal fishery in the Kattegat) the liberation of fry, no doubt, has yielded a profit during the whole period, the profit having likely reached a total of about 6,000 kr. per year.

Provided that the increase of the catch is a true result of the rational liberation of fry carried out since 1937 after the principles worked out by Otterstrøm—and several things point to the fact that this is really the case—we are allowed to conclude as follows:—

1. The success of liberation of artificially hatched trout fry does not depend alone on the number of fry liberated.

2. It is of the greatest importance to have the fry spread as widely as possible within the water area in order to utilize all places suitable for the growth of the fry and parr.
3. It is especially important to liberate the fry in such places, where natural spawning cannot take place—whether this is caused by blocking the access to them or by the bottom material not being suitable for natural spawning—provided the streams are suitable for the trout to grow up in them. In streams where there is free access for sea trout and plenty of spawning grounds, liberation seems to be useless (Larsen, 1955).

It is, however, also a compelling necessity to intensify the investigations on the biology and ecology of the trout fry in order to get exact knowledge about the demand of the fry on the surroundings. We also have to study thoroughly the causes of the losses from the fry stage to adult fish and, if possible, to find out how to diminish the dangers which threaten the trout between the two stages.

It would be preferable to have more examinations like this on the effect of liberation of trout fry. It demands, however, highly accurate information about the liberations as well as about the catch. I am sorry to say that in Denmark it has not been possible to get satisfactory information from other places than the Gudenå and Randers fjord, so there has been no opportunity to have the results here obtained submitted to a test in other localities.

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II. (2)

Experimental Analysis of the Young Salmon (*Salmo salar* L.) in the Stage of Transition to Life in the Sea

By

N. W. EVROPEIZEVA

In rivers, where in consequence of the construction of engineering works the process of natural reproduction of salmon is disturbed, smolts must be produced by fish farms. Rearing is interested in shortening the rearing period for the smolts. A study of the factors governing smolt formation both in ponds and under natural conditions was considered desirable in this connexion.

From work over many years information has been obtained on the following questions: (1) correlations between the processes of smoltification and the early ripening of the gonads of male salmon parr; (2) the phenomenon of desmoltification, which arises in smolts as a result of long delays in fresh water.

The experiments were carried out at the Peltshi (Latvia) fish farm in ponds having supplies of spring water. The ponds covered areas from 900 to 2,200 m² with average depths from 1.2–2 m. For rearing the salmon in the autumn/winter period, ponds were used which had an average depth of not less than 2 m. The experiments with young salmon in their second year of life were carried out in trout ponds, 130 m² each. The young salmon were planted at the following densities: fry, 2–3 per m²; fingerlings (in the autumn/winter period), 1 per m²; young in their second year of life, 1 per 1.5–2 m². Only naturally occurring food was available. The quantity of the food organisms (plankton and benthos) was increased by the Isakova-Keo zonal fertilization method (1957). Water and ground vegetation were chiefly employed for pond fertilization. The results of the experiments performed in the period 1951–55 have been published (Evropeizeva, 1957).

The material from nature was collected from the river Salazy, the adjoining estuary region of the Gulf of Riga, and the rivers Kola (region Murmansk) and Petchora. The young fish from the rivers Salazy (110 parr) and Kola (64 parr and 66 smolts) were caught on rod and line. In the Gulf of Riga the young salmon (65 smolts) caught in the seines used

for sprats were used in the investigation. Fixation of the gonads of salmon parr from the river Petchora (20 samples) was made by M. I. Vladimirskaia to whom we express our gratitude.

Ichthyological, histological, and biochemical methods were employed in the investigations of the young salmon. The peculiarities of the exterior and colour of the young of different ages and states, the growth-rates, the condition, the state of the sexual glands, of the thyroid gland and of the hypophysis were studied. Observations on the behaviour of the young were also carried out. At the same time the changes in the chemical composition of the body were studied by E. M. Malikova.

1. The Stage of Transition to Life in the Sea and its Realization in Ponds

The periods when the young salmon pass from the rivers (on the bottom) to the sea or lake (pelagic), which we single out as a special stage of individual development—the stage of transition to life in the sea or lake have been investigated by a number of authors (J. Berry, 1931; J. Lovern, 1934; F. Pentelow, B. Southgate, R. Bassindale, 1933; A. E. J. Went, 1938; K. Allen, 1944; G. Nikolsky, N. Gromtshevskaya, G. Morosova, and V. Pikuleva, 1947; L. Berg, 1948; W. Hoar, 1951, 1953; M. Fontaine, 1953; L. Arvy, M. Olivereau, 1954; N. Evropeizeva and L. Nusenbaum, 1954; N. Evropeizeva, 1954, 1955, 1957, 1958; E. Malikova, 1957; and others). During this stage significant physiological and morphological changes take place in the organs of the young salmon and intercommunication with its surroundings is essentially changed. These changes are due to the activity of the hypophysis-thyroid complex, the character of the metabolism, the chemical composition of the body, the mechanism of osmoregulation, the colour of the body, and the exterior. The adaptive sense of these changes consists in the preparation of the young fish for life in the sea. The whole transformation from a parr into

a smolt, the appearance of which is close to that of adult salmon, i.e. smoltification, takes place, to a considerable extent, under river conditions, partly in the estuary, and in some cases apparently preferably under estuary conditions. The approach of the transition stage to the mode of life in the sea depends on the attainment of definite minimum sizes and a corresponding level of development which permits the necessary re-organization of the organism in connexion with the transition into the new surroundings.

When rearing young salmon in ponds with a good food supply and normal water conditions these fish grow and develop rapidly thus accelerating the transition stage to life in the sea. Young salmon which by the beginning of their second year of life have attained a weight of about 15–17 g, as a rule, acquire in spring, at a water temperature within the range of 6–7° to 12–13°C and in running water, the colour and the characteristic external features of the smolt. At the same time other changes take place. The condition coefficient of the smolt, in comparison with that of the parr, is decreasing, the adipose tissue in the cavity of the body is disappearing, the chemical composition of the body is changing, all of which testify to changes in the metabolism. At the same time the behaviour of the young changes with these processes and the viability is lowered by the change (Evropeizeva, 1957).

Thus, in ponds with definite conditions, although different from those in the rivers, the realization of an historically proved adaptation is taking place, namely the accomplishment of the transition stage to life in the sea or in a lake, in respect to these characteristics of the young salmon that are connected with the transition into new surroundings. Pond-reared smolts, when released into the rivers, descended normally.

2. Smoltification and Ripening in Male Salmon Parr

Smoltification and ripening of the gonads in male salmon parr cannot take place at the same time, because these are processes with opposite biological meanings.

Some of the salmon parr (from 1% to 5–10%, seldom more) that reached the sizes at which the overwhelming majority begin smoltification do not turn into smolts. About 60–70% of such parr are usually ripening males (precocious parr). By rearing in ponds which are supplied with water from natural springs the manifestation of an early activity of the testes is revealed during the early months of spring. But the development of the majority of sexual cells

begins not earlier than the beginning of May. In this case early development of the gonads in male parr inhibits smoltification. Evidently, in the Baltic salmon this phenomenon is affected by the peculiarity of the conditions in the pond, which tend to approximate in time the approach of both processes.

The process of the ripening of the gonads of male parr and the process of smoltification are contrary biological processes. The first of these processes involves the preservation of the bottom mode of life, of the typical parr characters, and delays the descent of the young in the river. The process of smoltification, on the contrary, is connected with changes in the behaviour of the young salmon (transition to the descending migration) and with the formation of certain physiological and morphological characteristics. As a result, the young salmon obtains the characteristic exterior and colour of the smolt. This process is directed towards preparing the young salmon for the transition to life in the sea. Each of the above-mentioned processes—the early ripening of the male gonads and the smoltification—undoubtedly demand for their realization energy resources. During smoltification expenditure on fat and glycogen rises (Lovern, 1934; Fontaine and Hatey, 1950); the ripening male parr also have an increased expenditure on fat during the ripening of the gonads (Malikova, 1957). These data confirm the impossibility of both the above-mentioned processes taking place at the same time.

The temperature at which the process of spermatogenesis in the male parr can be carried out, varies very widely. With pond-reared salmon an increase in mitotic activity (spermatogonial divisions) in the testes of the ripening males can already be seen by the end of February or the beginning of March. Follicles, in which there are ripe sperms of the first spermatogenesis can be seen in the testes of a great number of males. The temperature in that period does not exceed 2.5° to 5° C. Probably, there is also a similar phenomenon in the river Kola. In the testes of one ripening male follicles with ripe sperm of a past spermatogenesis were also discovered (Figure 3). The early stages of spermatogenesis in male parr take place in ponds, as well as in the rivers Petchora and Kola, with gradually increasing temperatures. In Baltic salmon from the river Salazy, on the other hand, the early stages of the spermatogenesis take place at a temperature of about 18° to 20° and more (at the end of June or the beginning of July). The process of smoltification of the majority of salmon as our observations and experiments show, usually takes place under narrower limits of temperature—approximately from 6° to 7° to 12° to 13° C.

The ripening of the gonads of male parr in ponds

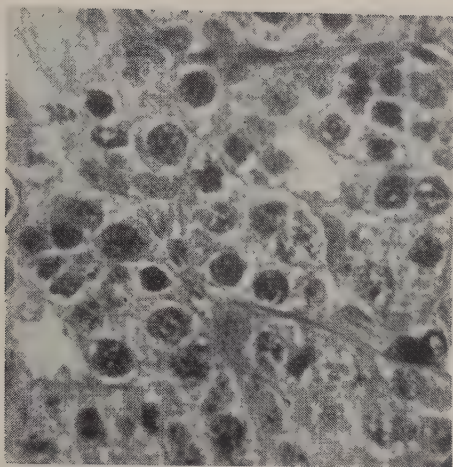


Figure 1. Testis of ripening parr at the beginning of spermatogenesis. Salmon from river Salazy, 25. June 1957. Body length, 12.5 cm; weight, 23.5 g; age, 1+. (Mag. 7×90 . Prepared by A. V. Neelov).

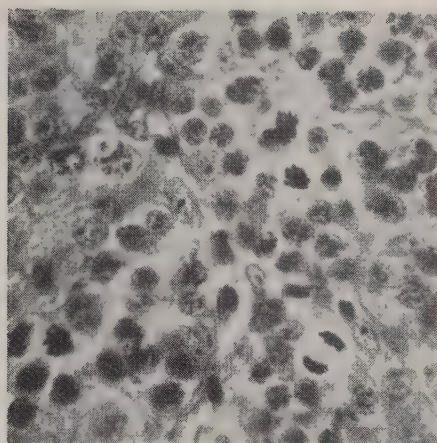


Figure 2. Testis of ripening parr at the beginning of spermatogenesis. Salmon from river Kola, 23. June 1959. Body length, 11 cm; weight, 14.8 g; age, 2+. (Mag. 7×90).

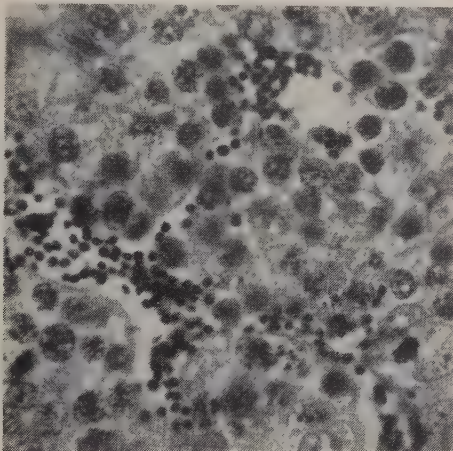


Figure 3. Testis of ripening parr at the beginning of spermatogenesis. Salmon from river Kola, 25. June 1957. Body length, 12 cm; weight, 18 g; age, 2+. (Mag. 7×90).

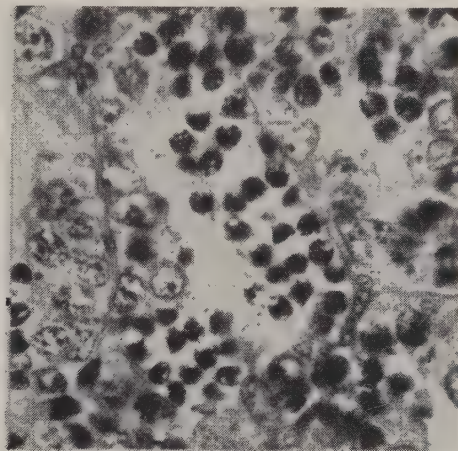


Figure 4. Testis of ripening parr at the early stage of spermatogenesis. Salmon from river Petchora, 18. June 1957. Body length, 11.5 cm; age, 2+.

has been observed when they have attained a weight of about 8 to 9 g, but the majority of the males ripen at a weight of about 13 to 15 g (see Table 1).

Table 1. The relationship between ripening of male parr in Baltic salmon and the weight of the body
(Pond material for April and May 1956 and 1957)

	Weight in g								Mean weight	Number
	5-7	9-11	13-15	17-19	21					
Ripe male parr.	-	3	11	18	23	14	10	7	14.4	86
Unripe male parr.	10	14	11	7	4	-	-	-	10.4	46

The lowest weight limit for the process of smoltification is usually much higher—about 15–17 g. In some cases some young salmon carried out the process of smoltification at a weight lower than 15 g and sometimes lower than 14 g. This was observed in ponds in 1955 and 1956 with spring food and constant running water in wintertime.

In rivers of Latvia the intensive growth in the second year of life of the young Baltic salmon promotes ripening of an overwhelming majority of the males and produces the descent of the young salmon at the beginning of the third year of life. The transition of the young to the descending state and

the process of ripening of the gonads of male parr takes place at different periods of the spring/summer season; the descent to the sea usually takes place in the first and second half of May, sometimes later, whereas the spermatogenesis in precocious male parr begins at the end of June or the beginning of July (Figure 1).

The process of smoltification does not occur in the majority of young salmon in the rivers of Latvia at the beginning of the second year of life, because at this time they have not reached the necessary size. In the same way spermatogenesis in the precocious males in the second year of life begins only after a definite period of intensive growth in the end of June or the beginning of July, during which the young attained the size which is necessary for its accomplishment. A similar correlation between the process of smoltification and the process of ripening of the gonads must, evidently, take place in rivers which are within the zones of moderate climatic conditions. In the rivers of England, for example, the descent of the majority of young salmon also takes place at the beginning of the third year of life, and the majority of the precocious male parr ripen in the second year of life (Jones, 1940; Jones and Orton, 1940).

Therefore the process of ripening of the gonads of male parr in these rivers cannot be the cause of a long delay of the young in the river. Males ripening for a second time in the river may be observed, but these are exceptional.

The early stages of spermatogenesis in the precocious male parr from the river Kola coincide with the period of transition of the majority of the young salmon to the descending migration (Figures 2 and 3). A similar phenomenon has been observed in the salmon of the river Petchora. Histological pictures of the testes from ripening male parr, at the period from 18. to 25. June 1957, show an intensively active spermatogenesis (Figure 4), but the descent of the majority of the young salmon takes place, usually, in this river in the second half of June (Vladimirskaia, 1957).

The majority, about 67%, of precocious male parr in river Petchora, ripen, according to the data of Vladimirskaia (1957) who examined 343 specimens, in the third year of life. About 29% ripen in the fourth, fifth, and even sixth year of life. The descent of the majority of the young salmon, however, takes place at the beginning of the fourth year. It is obvious that in the rivers Petchora and Kola the process of ripening of the gonads of precocious male can hinder the transition of some of the young salmon to the descending migration and is the principal cause of delay in the river. Such correlation

between the process of the ripening of gonads of precocious males and that of smoltification is evidently characteristic of the majority of northern rivers.

Thus, when there is a coincidence in time of the smoltification process and the process of ripening of the gonads of precocious male parr, the latter can be the principal cause of a long delay in the river of some of the young salmon.

3. Desmoltification of Smolts

Desmoltification of smolts during a long delay in ponds is a process of re-adaptation.

The salmon smoltification in the second year of life in ponds at the Peltshi fish farm usually takes place during the last ten days of April and the first half of May. The completed colour of the smolt and the characteristic traits of the exterior are well developed 15–16 days after the first appearance of the silver colouration. These pond smolts have the instinct to migrate downstream into the river, when released. A long delay (till autumn) of the salmon smolts in the ponds results in changes in their physiological and morphological characteristics towards those of the parr, namely towards desmoltification. The data relating to this process are given in Tables 2, 3, and 4 and in Figures 5 to 12. A detailed analysis of some young fish was carried out during the planting of young salmon in the ponds and the capture of the controls. The rest of the young salmon were let out into the ponds after determination (in life) of weight, length, and colour characteristics.

After a delay in the ponds one can see an increase in differences between the smolts and parr in indices which are characteristic of the exterior, the chemical composition of the body, the condition coefficient, and the presence of fat tissue in the body cavity. In about a month these differences are at their height (Figures 5 and 8). Evidently, under pond conditions the characters connected with the transition of the young salmon to the mode of life in the sea last for a certain period. After two or two and a half months (middle to the end of July) the characteristics of the smolts and the parr become similar. In the smolts condition improves, the percentage fat content and the condition coefficient increase, and fat tissue appears in the body cavity. The colour of the smolt gradually grows dull, a yellow-greenish shade and the parr marks on the sides of the body can be seen. By autumn the typical colour of the smolts disappears almost completely. The thyroid gland of the smolts in June showed signs of a lower functional activity when compared

Table 2. Characteristics of the young Baltic salmon in the ponds in their second year of life

Year	Date	Smolts (♀♀ and ♂♂ unripe and ♂♂ ripening)				Parr (♀♀ and ♂♂)				Smolts (♂♂ ripening)			
		<i>L</i>	<i>W</i>	<i>K</i>	$\frac{L}{H}$	<i>L</i>	<i>W</i>	<i>K</i>	$\frac{L}{H}$	<i>L</i>	<i>W</i>	<i>K</i>	$\frac{L}{H}$
1956	7/V	11.8	14.8	0.90	5.8	11.2	13.1	0.92	5.6	—	—	—	—
	18/VI	13.6	25.1	0.98	5.42	13.6	30.7	1.19	4.67	—	—	—	—
	24/VII	14.5	33.3	1.07	5.14	14.6	39.4	1.23	4.55	14.8	36.2	1.09	5.0
	21/X	18.6	70.6	1.07	4.98	17.8	64.2	1.12	4.99	18.6	75.14	1.17	4.49
	29/IV	12.9	22.4	1.04	5.11	10.9	15.6	1.20	4.83	—	—	—	—
1957	13/V	12.9	21.2	0.98	5.54	11.7	17.7	1.10	5.08	—	—	—	—
	16/VII	16.9	46.5	0.98	5.52	14.9	42.0	1.24	4.54	17.2	53.6	1.03	5.2
	12/VIII	18.1	59.4	1.04	5.24	16.0	52.2	1.25	4.55	18.6	68.8	1.06	4.72
	15/X	20.3	91.4	1.07	5.03	17.6	67.9	1.18	4.70	20.1	88.4	1.08	4.83

Symbols used in Tables 2—6:

L = length of body according to Smitt in cm.

lts = length of the caudal peduncle.

H = the greatest height.

$\frac{L}{H}$ = the index of lengthening.

K = condition coefficient $\frac{W \cdot 100}{L^3}$.

h = the smallest height.

h as percentage of *lts* = the smallest height as a percentage of the length of the caudal peduncle.

W = weight in g.

Note: in every case 10—30 fish of similar size were measured.

With one of the smolts caught in the estuary region of the river Salazy in the Gulf of Riga (Figures 10 and 11).

In the first period of the delay in the ponds (1 to 1½ months) the smolts show a lower growth-rate than the parr. In the next month the growth-rate in both groups of young salmon is similar, and in the last period the smolts are growing more rapidly than the parr. This was observed regularly by us during several years. The data of the two last years are given in Table 4 and Figure 9. The death of some of the smolts (up to 30 % and more) was observed during the period of delay. It was observed that desmoltification is more rapid when food supplies are good.

The young Baltic salmon descends from the river into the sea without any completed smolt colouration. The process of smoltification (second half of May and June) takes place mostly in the brackish zone of the Gulf of Riga. In this period the young salmon are often taken in seines used for sprats. These catches show that the young salmon live in waters of about 10 m to 15—16 m, with a preference for the former. The average temperature of the water fluctuates greatly in the second half of May, the five-day average is from 7° to 9° C at the surface, 1.5° to 7° at the bottom at a depth of 10 m; in June relevant figures are from 8° to 17.5° C at the surface and from 2.3° to 15° C at the bottom. The salinity of the water in this region is about 4 to 5 ‰.*) Smolts delayed in ponds live under quite different

Table 3. Changes in the fat content (as % of the dry weight) at desmoltification (according to Malikova) for young Baltic salmon in the second year of life in the ponds in 1957

Groups	Date		
	16/VII	12/VIII	15/X
Smolts..... ♀♀	9.03	11.48	18.19
Unripe..... ♂♂	7.55	8.98	20.26
Smolts..... ♂♂	12.95	12.61	15.91
Ripening			
Parr..... ♀♀	22.38	22.81	25.13
♂♂	22.92	24.65	19.57

Table 4. The average increase in the body weight as percentages for the ten-day period with young salmon in their second year in the ponds (1956)

	Periods		
	9/V to 18/VI	18/VI to 24/VII	24/VII to 25/X
Smolts.....	14.7	11.8	12.4
Parr.....	26.5	11.8	7.1

conditions. The depth of the ponds is not more than two metres. The temperatures of the water (the average for a five-day period) changes within the ranges: May, from 11.5° to 17.7° C at the surface and from 11.3° to 16.5° C at the bottom; June, from 13.5° to 22° C at the surface and from 13.3° to 19.5° C at the bottom (data for 1956 and 1957). The water in the ponds is fresh. Besides this, the space (the area of each pond was not more than 130 m²) and the weak flow must be taken into consideration.

The delay of smolts in ponds, where the conditions differ so much from those in the estuary in the

*) Data for 1956 and 1957 from the Baltic Department of NIRO.

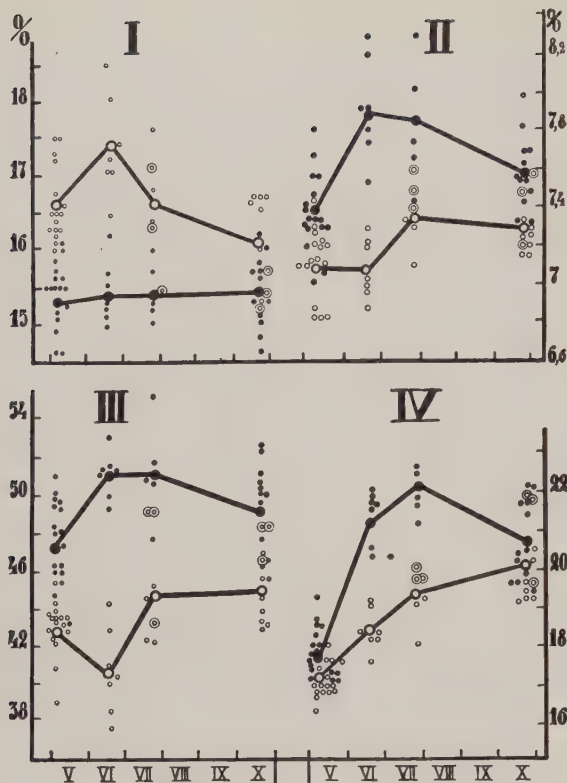


Figure 5. Changes in some indices characterizing the exterior of Baltic salmon in ponds, age, 1+ (1956).

- I. Length of the caudal peduncle as percentage of the body length.
 - II. The smallest height as percentage of the body length.
 - III. The smallest height as percentage of the length of the caudal peduncle.
 - IV. The biggest height as percentage of the body length.
- Open circles = smolts.
Black circles = parr.
Double circles = ripening males of smolts.

region of the Gulf of Riga, is a breach of the natural adjustment of the organism to its surroundings; the physiological and the morphological characters of the organism have changed but the conditions in which the young live as parr, are the same. We can therefore regard the process of desmoltification of the smolts as reversed adaptation of a changed organism to those former conditions, i.e., re-adaptation. The latter process brings about a greater conformity between the organism and its environment. Rearing of these "former smolts" in ponds produces in the following spring the transformation into typical smolts. The silvering process begins much earlier than in the smolts one year younger. These facts pin point still more the transition stage to the mode of life in the sea.

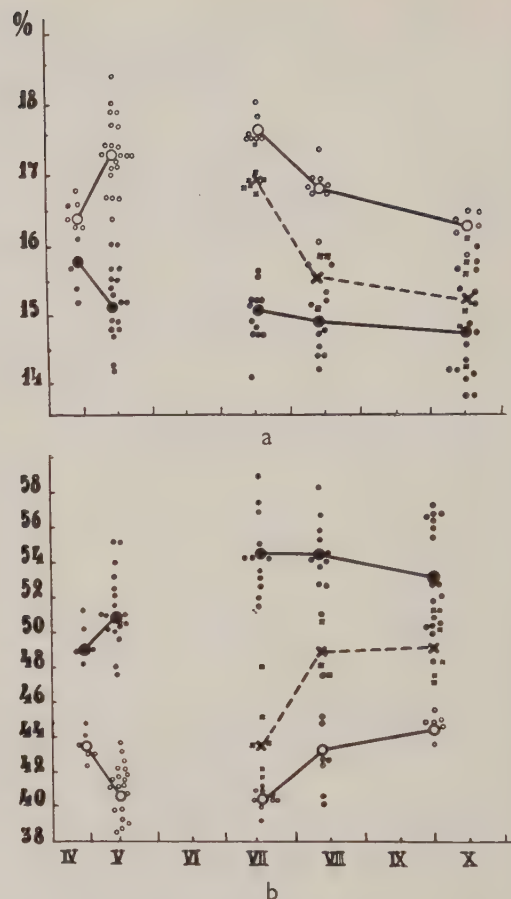


Figure 6. Changes in some indices characterizing the exterior of Baltic salmon in ponds, age, 1+ (1957).

- (a) Length of the caudal peduncle as percentage of the body length.
 - (b) The smallest height as percentage of the length of the caudal peduncle.
- Open circles = smolts.
Black circles and unbroken lines = parr.
Crosses and broken lines = ripening males of smolts.

4. Why is Early Ripening of the Gonads of Male Smolts Possible?

It has been shown previously that a simultaneous occurrence of smoltification and of ripening of the gonads of males is not possible. Histological study of the testes of smolts during the smoltification process has shown that ripening is observed mainly in the males, which were provided with conditions to permit intensive growth. In the middle of June (1957) or at the end of July (1956) a large proportion of the male smolts showed a small increase in the testes. Histological studies show that spermatogenesis was then just beginning (Figure 13). At the same time the testes of the precocious male parr

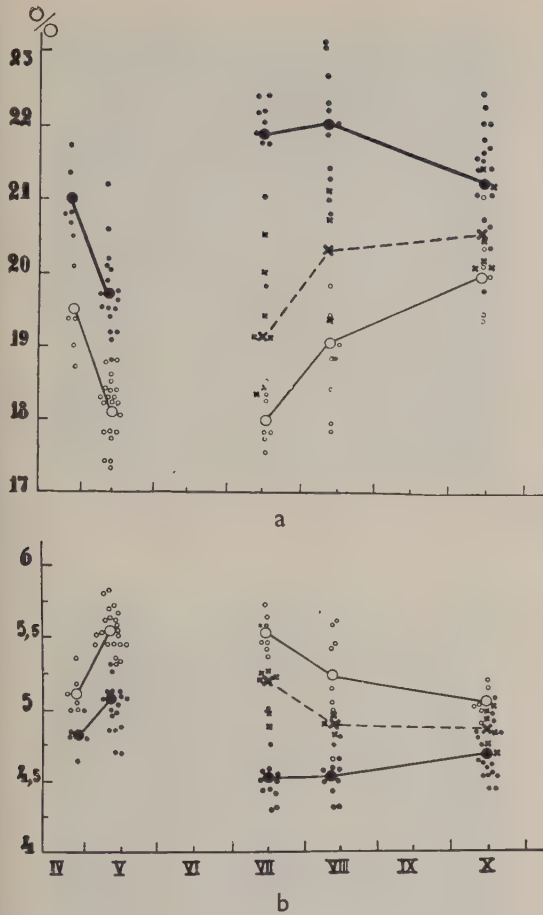


Figure 7. Changes in some indices characterizing the exterior of Baltic salmon in ponds, age, 1+ (1957).

- a) The biggest height of the body as percentage of the body length.
 b) Showing the length increment $\left(\frac{L}{H}\right)$. (Legend as Fig. 5).

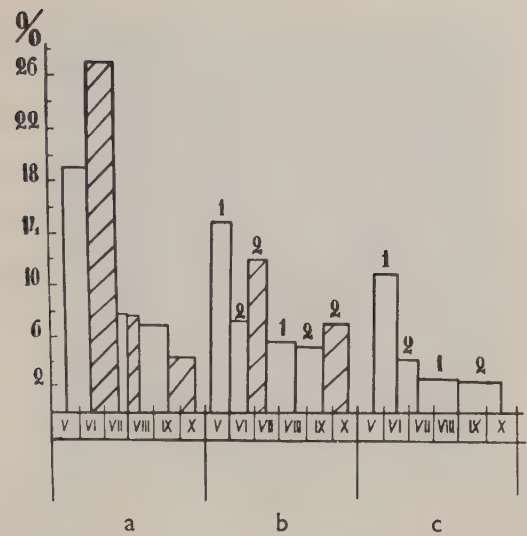


Figure 9. Average increases in the body weight as percentages for 10-day periods at desmoltification in the ponds in 1957.

(a) Baltic salmon at the age of 1+.

(b) Young salmon at the age of 1+: (1) Baltic salmon; (2) salmon of the river Kola.

(c) Young salmon at the age of 2+: (1) Baltic salmon; (2) salmon of the river Kola.

White columns denote smolts; hatched columns denote parr.

Figure 8. Changes in the chemical composition of the body at desmoltification in Baltic salmon from the ponds, age, 1+ (1956).

(After E. Malikova).

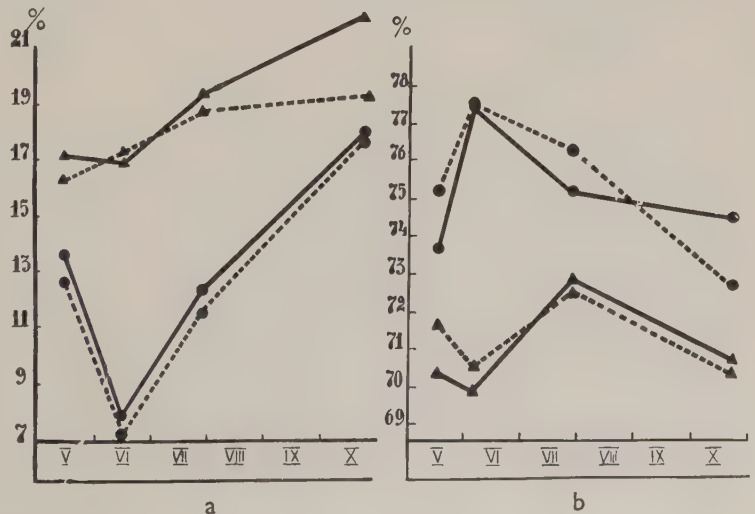
Open circles = smolts.

Triangles = parr.

Broken lines = males.

Unbroken lines = females.

- (a) The fat and (b) the albumen content as percentages of the dry weight.



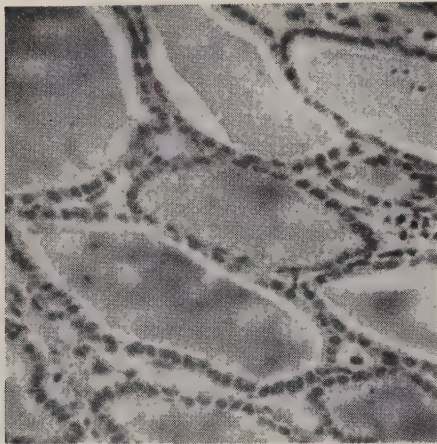


Figure 10. The thyroid gland of the smolts of Baltic salmon delayed in the pond. Body length, 12.7 cm; weight, 19.2 g; age, 1+. 14. June 1956. (Mag. 7×40).

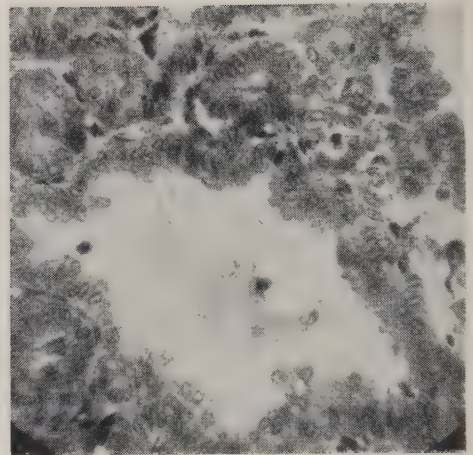


Figure 11. The thyroid gland of the smolts captured in the estuary of the Gulf of Riga. Body length, 15.4 cm; weight 38.5 g; age, 2+. 20. June 1956. (Mag. 7×40).

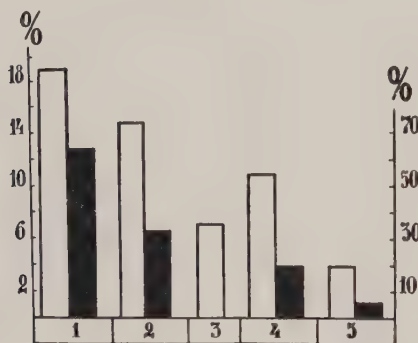


Figure 12. The relationship of the ripening male smolts and the growth-rate before the beginning of spermatogenesis. The white columns show the average increase of the body weight as percentages for the 10-day period; the black columns show the number of ripe males.

- | | |
|--------------------------------|---------------------|
| 1 and 2 = Baltic salmon | } at the age of 1+. |
| 3 = Salmon from the river Kola | |
| 4 = Baltic salmon | } at the age of 2+. |
| 5 = Salmon from the river Kola | |

had weights from 0.75 to 2.7 g and they had reached a later stage of spermatogenesis, i.e., the beginning of the spermatogenesis (Figure 14). Ripening of the gonads of male smolts is only possible, when they begin, in their physiological and morphological characteristics, to approach the parr, that is after the beginning of the desmoltification process. Therefore, the spermatogenesis in male smolts begins 2 to 2½ months later than in the precocious male parr. The ripening male smolts are in colour, exterior, and chemical composition of the body much closer to the parr than the unripe male smolts and the females (Table 3, page 33, and Figures 5 to 7).

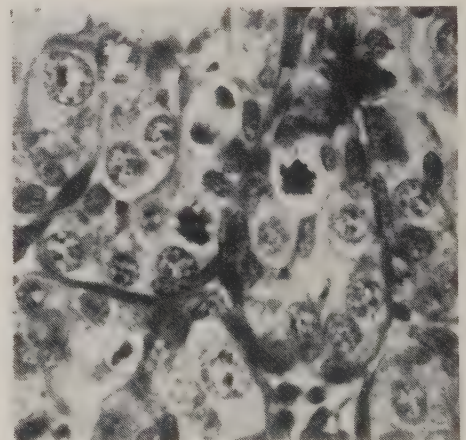


Figure 13. The testis of a ripening male smolt from the ponds at the beginning of spermatogenesis. Body length, 17.1 cm; weight, 59.9 g; age, 1+. 16. June 1957. (Mag. 7×90).

It is interesting to note that the testes of one of the ripening male smolts had attained the stage of spermatogenesis, similar to that of the parr (Figure 15). The colour and exterior of this male were the most similar to those of the parr (Figures 6 and 7). At the end of the first half of August there can be seen in the testes of the ripening male smolts the transition to the spermatogenesis (Figure 16). In the testes of male parr the spermatogenesis process had advanced much farther. The testes of the unripe male smolts were characterized by a resting state (Figure 17). In autumn it was found that 16 (66%) of the male smolts out of 24 investigated had ripening gonads; with the male parr—27 in number in-

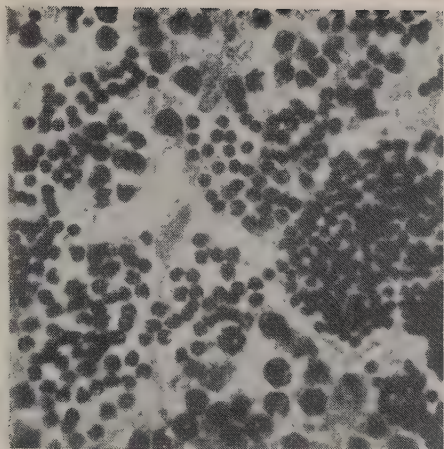


Figure 14. The testis of a ripening male parr from the ponds in the late stage of spermatogenesis. Baltic salmon, body length, 4.4 cm; weight, 39.1 g; age, 1+. 16. July 1957. (Mag. 7×90).

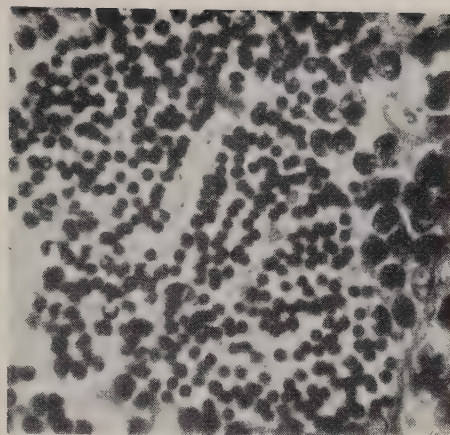


Figure 15. The testis of a ripening male smolt from the ponds in the late stage of spermatogenesis. Body length, 17 cm; weight, 57.2 g; age, 1+. 16. July 1957. (Mag. 7×90).

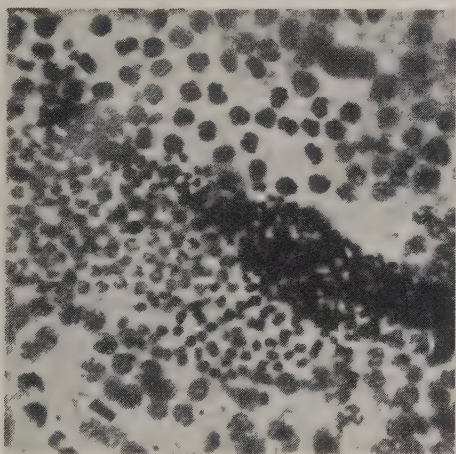


Figure 16. The testis of a ripening male smolt from the ponds in the late stage of spermatogenesis. Baltic salmon, body length, 16.1 cm; weight, 63.3 g; age, 1+. 12. August 1957. (Mag. 7×90).

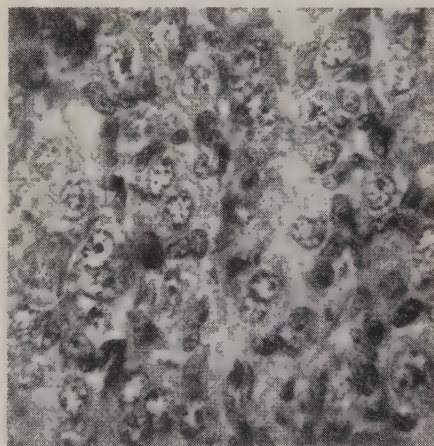


Figure 17. The testis of an unripe smolt from the ponds in the resting stage. Baltic salmon, body length, 18 cm; weight, 56.2 g; age, 1+. 12. July 1957. (Mag. 7×90).

investigated—all had ripening gonads. Similar correlations were observed in one of the ponds in 1956. It appears that the more rapid the growth-rate of smolts at the period preceding the spermatogenesis, the larger the quantity of males with ripening gonads (Figure 12).

The ripening of the gonads of male smolts only during their desmoltification is a direct experimental confirmation of the thesis that smoltification and ripening of the gonads of precocious males are processes that are with opposite biological meanings. The accelerated rate of desmoltification in ripening of male smolts proves their greater plasticity in the process of re-adaptation.

5. Peculiarities of the Desmoltification Process in the Salmon from the River Kola

In salmon with different ecologies in the transitional stage to the mode of life in the sea one may expect differences in the course of the desmoltification process too, especially physiological differences. The Baltic salmon and the salmon from the Barents Sea are distinguished, in the first instance, because they descend from the rivers into surroundings with different salinities. The Baltic salmon descend from the river Salazy into the brackish zone of the Gulf of Riga, where the greatest salinity does not exceed 4 to 6 ‰. Salmon from the river Kola descend into an estuary region, where the salinity is subject to rather

Table 5. The characteristics of the salmon smolts from the river Kola and the Baltic salmon in the second year of life in the ponds in 1956

Date	Forms of salmon	L	in ‰ of body length			$\frac{h}{L}$	$\frac{L}{H}$	W	K	in ‰ of the dry weight			
			lts	H	h					Fat		Albumen	
10—15/V	Salmon from River Kola	12.8	17.3	17.8	7.0	40.8	5.6	19.9	0.91	14.08	13.94	73.84	72.30
	Baltic salmon	12.2	16.7	17.7	7.0	41.7	5.6	17.0	0.93	13.56	12.84	73.86	75.86
14/VI	Salmon from River Kola	13.5	17.6	16.9	7.0	40.3	5.9	21.9	0.81	9.31	7.98	75.23	78.62
	Baltic salmon	13.3	17.0	17.8	7.1	41.7	5.6	22.0	0.91	7.87	7.16	77.48	77.54
20/X	Salmon from River Kola	18.0	36.2	19.2	7.3	45.0	5.2	60.9	1.01	13.25	18.46	76.5	72.42
	Baltic salmon	18.0	15.6	19.2	7.3	46.8	5.2	60.9	1.02	13.72	18.99	77.0	71.08

Table 6. The characteristics of the descending young salmon from the river Kola and the Baltic salmon from the Gulf of Riga

Forms of salmon	Place and date	L	in ‰ of the body length			$\frac{h}{L}$	$\frac{L}{H}$	W	K
			lts	H	h				
Salmon from River Kola	River Kola 21 to 26/VI/1957 . . .	14.8	16.7	18.4	7.0	41.9	5.30	32.6	1.0
Baltic salmon	Gulf of Riga 25 to 26/VI/1956 . . .	15.2	16.9	17.9	6.9	40.0	5.6	30.9	0.88

sharp fluctuations. The following fluctuations of the salinity in 4 to 5 km from the mouth of Kola are as follows:—

At surface	—	Fresh water	to 16.38 ‰
At 3 m	—	1.84 ‰	to 30.68 ‰
At 5 m	—	4.63 ‰	to 32.79 ‰

In depths greater than 8 m the salinity does not fall lower than 30 ‰ (Derjugin, 1915).

The investigations of the smoltification process in the Baltic salmon in ponds and in salmon from the river Kola do not reveal any significant differences. The exterior, colour, chemical composition of the smolts' body in both forms are rather similar (Table 5). The salmon smolts from the river Kola were a little more slender.

Similar data were obtained also by comparison of the characteristics of Baltic salmon with those of the salmon from the river Kola as regards the desmoltification (Table 5). The young salmon from the river Kola, caught during the descending migration, have some differences from the descending young Baltic salmon, caught in the Gulf of Riga soon after the smolt descent (Table 6). The latter are characterized generally by being more slender and with a lower condition coefficient. The observed differences can be attributed to the earlier development of smolt characteristics in the river Kola, when compared with that of the Baltic salmon. Thus we can arrive at the conclusion that the young salmon from the river Kola descend at the very beginning of the smoltification process, the principal part of which

evidently continues (as in the case of the Baltic salmon) in the regions of the Kola Bay estuary.

The study of the desmoltification process in salmon smolts from the river Kola and in the Baltic salmon in the second and third years has shown that the former possess a lower adaptive plasticity. This is expressed by a reduction in the growth-rate during the first delay period in ponds and by an almost complete absence of ripening male smolts. The smolts from the river Kola in the second year showed a growth-rate half that of the Baltic salmon smolts (Figure 9). There were no ripe males among the smolts from the river Kola (Figure 12). In smolts in their third year the growth-rate during the first delay period in ponds was only a third of that in the Baltic salmon of the same age (Figure 12).

Arvy, Fontaine, and Gabe (1955) have shown that complicated changes are taking place in the hypothalamo-hypophysis' complex of the descending young salmon in connexion with the change of the water/salt metabolism during the transition into surroundings with increased salinity. In this connexion we are inclined to explain the observed differences in the desmoltification process as adaptation of salmon smolts from the river Kola, at the present stage of their development, to life in more saline surroundings than the Baltic salmon.

We intend to carry out in future comparative studies of the transition stage to the mode of life in the sea in forms of salmon which have sharply contrasting ecologies (lake-salmon and salmon from the White Sea and the Barents Sea).

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II. (3)

The Amplitude of the Smolt Production of the Swedish State Power Board

By

ERIK MONTÉN

At present it has been calculated that the total hydroelectric resources capable of being developed in our country amount to 80 milliard kWh/annum. About 20 % of these resources had been exploited before 1950. These earlier developments had only in certain cases and most often to a small extent reduced the smolt-producing capacity of the rivers. Probably at least 80 to 85% of the natural smolt production had been left intact by the power developments, and the salmon regions of the most important rivers in Norrland were at that time quite intact. About 1950 the demands of power began to force the building of power stations in the Norrland rivers, and now the damage to the salmon production increased considerably. At that time the output of reared smolts began to be considered the best method to maintain a salmon stock damaged by the development. A great deal of those falls which are situated in the salmon regions of the Norrland rivers, are owned by the State. When these rivers are now going to be developed the State Power Board thus has to arrange for a continually increasing smolt rearing. Following the programme of the power developments planned by the Board for the next 10 years and the principles which are at present used to calculate the required number of smolts to compensate for the damage to reproduction, the Board has reckoned that the need for salmon and sea-trout smolts will rise from 90,000 to about 800,000 (see Figure 1). The total need of smolts with regard to the State Power Board and the private developments is calculated to rise from about 350,000 to about 1.7 millions during the same period. As it generally takes one or two years to build a modern complete plant for smolt production and two or three years to produce a smolt, the erection of new hatcheries which are intended to produce a new smolt liberation in 1962, must already be under construction this year (1958).

The Power Board began in 1952 to rear smolts on a small scale at a hatchery at Forsmo and at present the Board has reached a production from all hatcheries of 125,000 smolts and over 300,000 smaller young of trout and grayling.

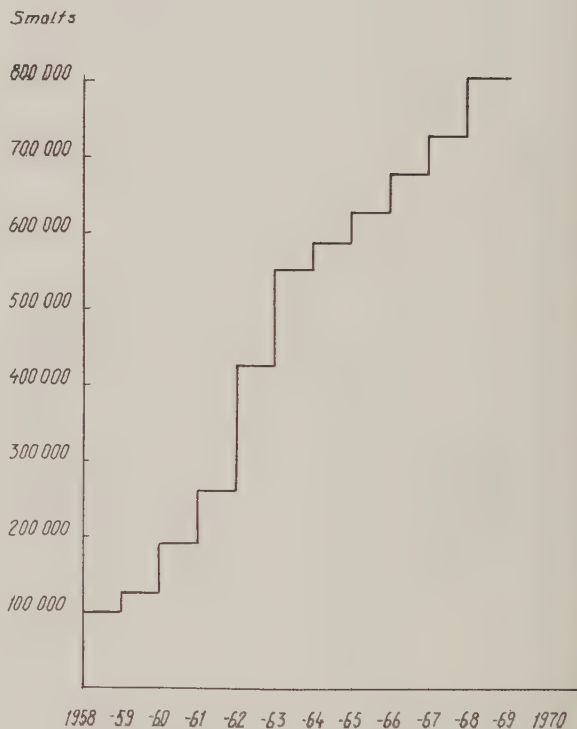


Figure 1. Estimated production of smolts of the Swedish State Power Board.

The present and future smolt production of the Board is based on the following plants and projects.

1. *The Salmon Research Laboratory* situated at Hölle power station in the river Indalsälven. The most important tasks of the laboratory are the investigations and experiments for which the Migratory Fish Committee is responsible. The rearing of smolts has for the past three years been directed to an annual production of 75,000 smolts. In 1958 the production reached about 54,000 smolts.

2. *Forsmo and Blåsjön*. At Forsmo on the river Ångermanälven the Power Board had earlier a small hatchery for summer rearing. Those and two-summer-old parr, which were meant for further rearing, were

transported to a wintering station with a good supply of spring water, Blåsjön, situated in the neighbourhood of Hölle on the river Indalsälven. In 1957 a new smolt-rearing station was built at Forsmo with both hatchery and wintering room as a compensation for the old Forsmo hatchery. The wintering station at Blåsjön has been extended this year, and it will be used in wintering the parr reared at Forsmo. Forsmo and Blåsjön are at present producing about 50,000 smolts but an annual production of 125,000 smolts in the next few years is estimated and furthermore considerable quantities of one- and two-summer-old parr of trout and grayling.

3. *Norrfors and Vindeln*. At Norrfors on the Umeälv a hatchery was built which should be used for salmon fry production. The hatchery has now been altered to a hatchery and rearing station for smolts and wintering house for one summer-old parr of trout and grayling, which are reared in a smaller summer rearing station at Vindeln about five Swedish miles north of Norrfors. Norrfors and Vindeln have together a production capacity of about 5,000 smolts.

4. *Porjus*. This is the northernmost station of the Board situated above the Arctic Circle. It was originally built for rearing of one- and two-summer-old fish. It has now been completed with a better wintering house and a food preparation room and can, besides the summerlings, produce about 10,000 smolts.

5. *Munka-Ljungby* in NW Skåne. This is a rainbow trout rearing station and does not belong to the Swedish State Power Board. It is private property and the largest commercial trout-rearing station in Sweden. Recently it has been modernized on the

pattern of the Danish fish cultural establishments. By contract with the Power Board, the producer is experimentally rearing smolts by directions of the fishery biologist of the Board. The smolts are transported by car to Norrland for liberation. The production is at present about 20,000 smolts per year.

From 1961 the need of smolts is estimated to exceed the whole capacity of the above mentioned rearing stations, and in 1962 the whole need of smolts presumably will exceed 400,000 smolts. As a consequence it is necessary to enlarge the number of rearing stations. These new rearing stations are, like Forsmo, generally constructed for an annual production of 125,000 smolts.

6. The first of these is *Näs* on the river Dalälven. It is under construction and the production is calculated to begin with one-summer-old salmon in the autumn of 1959. The first smolt contingent will be ready for liberation in the spring of 1961.

7—8. To meet the increased need in 1962, two smolt plants are planned in detail. One of them is intended to be erected at *Älvkarleby* on the river Dalälven and the other one at *Långhult* in Småland in southern Sweden.

9—10. Some additional smolts may be needed about 1965—1968 to compensate for the whole smolt production of the river Luleälv. We are going to produce these, partly by enlarging the already existing rearing station at *Norrfors*, partly by erection of a new one in Småland, possibly at *Ugnanäs*.

Therefore, in 10 years the Swedish State Power Board is reckoning upon about 10 smolt-rearing stations with a total annual production of more than 800,000 smolts.

II. (4)

Freshwater Species of Salmon and their Significance in the Origin of the Salmonidae and Practical Fish Culture

By

N. I. KOSHIN and A. A. PROTASOV

In 1948 Berg published two papers in which the first attributed Caspian salmon to the subspecies of *Salmo trutta* and defined it as *S. trutta caspius* Kessler. In the second paper he considered Caspian salmon as *S. salar caspius* Kessler, but he added that if the Caspian salmon is a genuine salmon (from *S. salar*) then it cannot be related to Caucasian trout, as it is known that only males occur in the dwarf forms of salmon in the rivers, whereas both males and females are encountered amongst Caucasian trout. He also considered that it was possible for *S. salar* to penetrate into the Caspian Sea, for instance through the upper tributaries of the Petchora and the Kama (a tributary of the Volga). A. N. Derzhavin (1956), on the other hand is of the opinion that the Caspian salmon originated from the trout populating the rivers of the Caucasus, and he defined it as *S. fario caspius* Kessler.

Caspian salmon migrate to the rivers for spawning. Within the territory of the USSR most of these salmon enter the Kura river from November to February with immature gonads which mature in 8 to 12 months ("winter" form of Berg, 1948).

Females predominate in the catches of the "winter" forms and they may comprise more than 90% of the total. Females make up about 60% of the catches of the "spring" form.

The Mingechaursk dam, built in 1952, obstructed the passage of salmon to the spawning grounds which were situated in both the upper part of the Kura river and its outfall. Natural spawning areas were retained only in the basin of the Arax river flowing into the Kura river below the Mingechaursk dam.

Two salmon rearing stations were built and put into operation in the basin of the Kura river (Azerbaijan SSR) to preserve the resources of Caspian salmon. Experiments were conducted at the Chaykend rearing station in order to obtain freshwater forms of Caspian salmon, for the purpose of ascertaining their biological peculiarities, origin and improvement of the rearing processes. The experiments carried out in Scotland in 1885 and 1886 and in Denmark

from 1926 to 1932 served as the bases for these experiments. In December 1880 in Scotland young salmon, reared from artificially fertilized ova, were planted into ponds. In 1884 ova and milt were obtained from smolts from these ponds and successful artificial fertilizations were carried out. Some females had already matured in the ponds by December 1883 at the age of 3 years (Day, 1885; Berg, 1935).

Six thousand young fish from two salmon (*S. salar*) caught in 1926, were obtained and used for stocking ponds in Denmark in the spring of 1927. By the spring of 1930 all the males and some of the females had matured and artificial fertilization was carried out. In autumn of 1931 all the salmon in the ponds were again mature and another artificial fertilization was carried out. These salmon grew slowly in the ponds and weighed about 1 kg. One female produced about 1,500 eggs. At the age of 5 years the females hatched in 1927 reached 42 cm in length and weighed 725 g (Otterström, 1933; Berg, 1948).

At the end of 1951 the yearlings that had been obtained as a result of artificial fertilization of the "winter" forms of Caspian salmon were placed in wooden tanks (2.5 m × 0.7 m × 0.6 m) for rearing at the Chaykend experimental rearing station. Rearing continued until November 1954. By the end of the experiment 15 fish about 4 years old had survived, of which there were 12 females and 3 males. The average weight of the fish was 394 g.

It should be noted that the greater part of the reared males already had mature gonads by the end of 1953.

During rearing the salmon were generously fed with such different food stuffs as *Enchytraeus*, spleen, fish meal, meat and bone meal, and blood. To artificial (dead) food stuff rye flour was added. In small amounts the salmon received tadpoles, gammarids, maggots, earthworms, etc.

In November 1954 artificial fertilization was carried out with 12 tested females. The ova of 8 females were fertilized by the milt of 3 salmon males hatched in 1951, i.e., of the same age as the females. Four

females were fertilized by the milt of four males hatched in 1952 and also reared in fresh water under artificial conditions. Altogether 12,360 eggs were obtained from the 12 fertilized females or 1,030 eggs from each female. The average weight of the females was 250 g. As to their outward appearance the salmon reared in fresh water resembled salmon more than trout.

These experiments were continued in 1952 and 1953. Young fish of the "winter" form of Caspian salmon hatched in 1952 reached the smolt stage by November 1953. A small number of smolts were left at the experimental station for further rearing under freshwater conditions and by 1. January 1954 there were 250 specimens of these young fish with an average weight of 20 g. During 1954 the young were reared in a wooden tank and they were also fed with various natural (alive) and artificial foods. By the end of October 1954 the weight of these young fish averaged 112 g. The greater proportion of the males had mature gonads and some of the females had also reached maturity. Experimental data show that 85% of the males and only 10 to 15% of the females of Caspian salmon, reared in fresh water, ripen at the age of 2+ years. All the males and females of Caspian salmon, reared in fresh water, were ripe at the age of 3+ years. In November 1954, the ova obtained from the females, hatched in 1952, were fertilized. The fertilized ova from the females hatched in 1951 and 1952 were put in the Shuster apparatus for incubation, whereas females in both years were separately stocked, according to age, into the ponds of the type of a "trout ditch". These females were reared till the end of 1955. In November 1955 the ova obtained from 11 females hatched in 1951 was fertilized with the milt of the males (hatched in 1951, 1952, and 1953) and reared in fresh water. The average weight of these females was 687 g. In all, 18,084 eggs were obtained, or an average of 1,644 eggs from each female. In November 1955, also the ova from 12 females, hatched in 1952 and from 5 females hatched in 1953 and reared in fresh water were fertilized. The average weight of females hatched in 1952 was 373 g. In all, 9,456 eggs were obtained (788 eggs on an average per female). The average weight of females hatched in 1953 was 173 g, and 1,590 eggs were obtained (330 eggs from one female).

Thus, the ova obtained from females hatched in 1951 (for the third time), from females hatched in 1952 (for the second time), and from females hatched in 1953 (for the first time) were fertilized in November 1955. In 1956, after the incubation of the eggs the fry were first kept in the Shuster apparatus, and then transferred first into rectangular tanks and after reaching 650 mg weight, into round basins of the

system developed by VNIRO (a modernized type of the round Seetowne basin).

The average weight (g) of young in December 1956

Breeders	Total number in thousands	Average weight of the young
<i>The experiment</i>		
Females hatched in 1951..	6	2.28
Females hatched in 1952..	2.5	2.15
<i>Production</i>		
Females of large descending salmon.....	175	2.26

In January 1957, all the young salmon hatched in 1956 were planted into one round basin. By May 1957, out of 8,500, 7,000 had survived, a considerable proportion being near the smolt stage. The final transition into the smolt stage was recorded in January 1958.

The weight of young salmon by the end of rearing averaged 25 g. Some were partially tagged and released into the Kura river. According to morphological characters and colour, the smolts obtained from dwarf females that had been reared in fresh water (the ova were fertilized by dwarf males) did not differ from smolts, obtained from the breeders of the "winter" form of descending salmon of the Kura river.

Simultaneously with the above experiments similar experiments were conducted in 1956 and 1957 by D. A. Panov at the Charnorechensk salmon rearing station (the Georgian SSR) on Black Sea salmon (*Salmo trutta labrax* Pallas). This salmon enters the rivers, flowing into the Black Sea, mainly from the Caucasian coast, for spawning. G. P. Barach holds that the Black Sea salmon and stream trout of the Caucasian rivers of the Black Sea (*S. trutta labrax* Pallas *morpha fario*) make up a single stock (Barach, 1952 and 1957). Recruitment of the stock of Black Sea salmon takes place at the expense of the young of both salmon and trout which descend into the Black Sea. D. A. Panov conducted the following experiments. He artificially fertilized trout ova with trout milt, ova of salmon with salmon milt and ova of salmon with trout milt. Then the young fish obtained after incubation were segregated and reared separately. After 18 months, in June 1957 up to 40% of all the young fish began to turn into smolts. No differences in morphological characters were recorded. According to Panov, these experiments confirmed Barach's supposition that Black Sea salmon and the trout of the Black Sea rivers form a single stock (Panov, 1958).

Stream (river) trout can descend to the sea and turn into descending forms (*S. trutta*) and *S. trutta* can also produce freshwater forms of trout (*S. trutta morpha fario*). However, it has already been pointed out that recruitment of the stock of *S. trutta* takes

place at the expense of descending adult trout and not of young fish. Dwarf (freshwater) immature males occur and dwarf (freshwater) females were obtained under experimental conditions. It follows that the presence, or absence, of freshwater forms of males and females cannot serve as the basis for attributing salmon to one or the other forms of *S. salar* or *S. trutta*.

The above mentioned experiments with Caspian salmon lead us to assume that Caspian salmon and Caucasian trout are transitory forms from one to another, and as in the case of Black Sea salmon, we are dealing here with the form *S. trutta caspius*. It should be noted, however, that further research is needed especially in respect to *S. salar*.

In conclusion the importance of experimental studies for establishing the origin of the genus *Salmo* should be stressed. Our experiments also showed that it is quite possible to use both dwarf (freshwater) males and females for artificial breeding of *S. trutta*. There is no doubt that dwarf males which can be successfully reared in rearing stations (Protasov, 1955) may be used for artificial breeding of *S. salar*.

Summary

Caspian salmon migrate from the Caspian Sea to rivers for spawning. The majority enter the Kura river from November to February with immature gonads which mature within a period of 8 to 12 months ("winter" form L. S. Berg). Sexually mature salmon also enter the river in October and November and they spawn within 2 to 3 months, but they are only present in insignificant numbers ("spring" form L. C. Berg). There is a predominance of females (up to and over 90% has been recorded in catches of "winter" forms). The females provide approximately 60% of the catches of the "spring" forms.

At first Berg was under the impression that the Caspian salmon was a subspecies of *Salmo trutta* i.e., *S. trutta caspius* Kessler. Later, however, he defined it as a subspecies of *Salmo salar*—*S. salar caspius* Kessler. According to Berg, *S. salar* might have penetrated into the Caspian Sea, for instance, through the system of tributaries of the Petchora and Kama (a tributary of the Volga). A. N. Derzhavin states that the Caspian salmon originated from the trout present in the rivers of the Caucasus, and he defines it as *Salmo fario caspius* Kessler. Berg also points out that if Caspian salmon is really *S. salar*, then it cannot be related to Caucasian trout, because it is known that among dwarf forms of salmon only males are usually observed in rivers, whereas both males and females of Caucasian trout are encountered.

It is known, however, that dwarf freshwater forms of male and female *Salmo salar* were experimentally produced in ponds in the 1880's in Scotland, and in the 1920's in Denmark, when artificial fertilizations were carried out.

Dwarf freshwater forms of males and females were also obtained as a result of similar experiments with Caspian salmon in the years 1951 to 1957. Furthermore, smolts were reared from these freshwater females and males, which did not differ morphologically or in colour from the smolts of the "winter" form of the Caspian salmon. Thus, both *S. salar* and *S. trutta* have dwarf (freshwater) forms of males and females. Hence, the presence or absence of female and male dwarf freshwater forms cannot serve as evidence for the determination of salmon as either *S. salar* or *S. trutta*.

The above mentioned experiments with Caspian salmon confirm the supposition that Caspian salmon and Caucasian trout are forms which naturally transform into one another and here as in the case with Black Sea salmon we deal with the form *Salmo trutta caspius*.

In conclusion, it is necessary to note the significance of the experimental studies establishing the origin of the genus *Salmo*. The above mentioned experimental studies also showed that it is possible to use both dwarf (freshwater) males and females for artificial rearing of *S. trutta*. There is no doubt that dwarf (freshwater) males, which can be successfully reared in hatcheries, can be used for artificial propagation of *S. salar*.

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II. (5)

On the Efficiency of Natural Propagation in Atlantic Salmon (*Salmo salar* L.)

By

I. I. LAGUNOV and V. V. AZBELEV

Beginning in 1950, the Polar Institute of Marine Fisheries and Oceanography and the Murmansk Department of Fish Conservation have been carrying out investigations on the biology of Atlantic salmon (*Salmo salar* L.) and observations on variations in its abundance in three rivers of the Kola peninsula. To a certain degree our investigations continue the research work done by the salmon expedition of the Institute of River and Lake Fisheries in 1930–1933. Our methods are based on the investigations of Pacific salmon of the genus *Oncorhynchus*, conducted in a number of rivers flowing into the Pacific Ocean. Our main object is the elucidation of coefficients which reflect the relationship between the number of breeders, the quantity of deposited eggs, and the numerical strength of the year-classes.

The main drawback of the fishery of today is its more or less erratic development, which has little regard to the level of abundance of the exploited stock. Although in salmon fisheries the migration of breeders to the spawning grounds is assured by special fishery regulations, these regulations cannot, even granted their highest flexibility, control, separately, the fishing of large and small year-classes.

Therefore estimates of maximum catches of spawners will be a valuable contribution to the rationalization of the salmon fisheries.

At present the bulk of the catch is taken in coastal waters; relatively small numbers of salmon are caught in rivers. In the future, knowing the mean coefficients characterizing the return from a given number of females, it would seem advisable to organize salmon fishing on a rational basis, i.e., to discontinue fishing in the sea and transfer the fishing operations to the lower reaches of rivers where, knowing the structure and the abundance of the populations, it will be possible to control the escape of breeders to the spawning grounds and the catch of the commercial fish. Concentrated fishing and escapement could be achieved by means of wooden racks put across the rivers, or by barring the rivers

with pound-nets of the Far-Eastern type. This will permit the evaluation of the productivity of different rivers and the protection of the less numerous year-classes, and we would furthermore obtain a better insight into the biology of different populations of salmon. Obviously the new system will be successful only on condition that the river management will prevent fishing for spawners and provide for their spawning and for a high survival of the fry.

In accordance with the above statement, countings are made annually of all fish caught, as well as of fish allowed to escape to the spawning grounds of the rivers Tuloma and Kola, flowing into the Barents Sea, and of the river Kolviza flowing into the White Sea. Parallel with the counting of fish systematic observations were made on age and sex composition of the spawners, their fecundity, etc. The salmon populations of the Kola Bay and the river Kolviza are small numbered, but we do not consider this a drawback impairing our work, since only small populations can be exactly evaluated—which is a requisite for the elucidation of general principles. As the counting of breeders in the rivers mentioned above was started at different times, complete data (except group 7+ in the oldest year-classes) are available for six year-classes of Tuloma salmon but only for four year-classes of salmon from the Kolviza. No sufficient data have, as yet, been received for the salmon of the Kola river so that in this report only the spawners entering the rivers Tuloma and Kolviza are being considered.

The age compositions of these spawners is given in Table 1. For the sake of simplicity we omit the number of years from hatching to downstream migration and indicate only the total number of years of life.

The table shows a preponderance of older fish in the spawners of Tuloma salmon. As seen from Table 2, this is due to the shorter phases of river and marine life observed in the Kolviza salmon.

The shorter phases account also for differences in

Table 1. Age composition of the populations investigated

River	Age-groups (%)					Second time migrants	Number of fish investigated
	3+	4+	5+	6+	7+		
Tuloma.....	8.0	35.0	38.5	15.0	2.5	1.0	4,992
Kolviza.....	30.0	41.3	21.0	6.2	0.5	1.0	2,255

Table 2. Freshwater and marine phases

River	River phase Age-groups (%)				Marine phase Age-groups (%)				
	2+	3+	4+	5+	1+	2+	3+	4+	5+
Tuloma.....	12.8	65.2	19.9	2.1	30.8	47.5	20.0	1.7	very seldom
Kolviza.....	48.7	47.9	3.3	0.1	65.9	35.9	7.9	0.3	

Table 3. Results of reproduction of four year-classes of the Kolviza population

Year of spawning	Number of spawners	Probable quantity of eggs in females escaped to the spawning grounds (in millions)	Number of adults returned					Ratio of breeders to number of fish in a year-class	% of probable quantity of eggs in females	Number of fish returning to the river for a second time	% of fish in the year-class	Total
			3+	4+	5+	6+	7+					
1945	135	0.663	98	261	126	43	7	535	1 : 3.96	0.09	1 8 4	13
1946	165	0.816	62	245	78	39	2	425	1 : 2.57	0.05	- 3 8	11
1949	220	1.088	168	429	149	92	6	844	1 : 3.83	0.08	- 1 -	1
1950	260	2.189	616	271	502	33	?	1,322	1 : 5.08	0.06	1 3 ?	4

fecundity, which averages 8,500 eggs per female in the Tuloma salmon and 10,400 eggs per female in the Kolviza salmon.

As regards our data bearing on the total survival of salmon, it must be noted that they were obtained during a period of increasing abundance; therefore our coefficients of return from a certain number of breeders cannot be considered as characteristic of mean long-term ratios.

Table 3 contains data on the reproduction of the Kolviza population. No information is given concerning fish older than 7+, as they are represented only by single individuals. It can be seen that the numerical strenght of these year-classes exceeds the number of breeders in the escapement by 2.57–5.08 times. The rate of total survival, 0.05–0.09, cannot be regarded as a high one, being much lower than the rates reported by Soviet and foreign investigators for sockeye (red) salmon.

Much the same figures were obtained for the Tuloma salmon (Table 4). Information regarding the quantity of eggs in females, allowed to escape to the spawning grounds, will be available only for the year-classes produced by the spawning of 1952 and later. For the period 1945 and 1950 the average rate of total survival can be approximately calculated, since we know the average sex ratio and the average fecundity of the Tuloma salmon.

Table 4 shows that the coefficients characterizing the return of Tuloma salmon from a certain number

of breeders varied within a wider range than those obtained for the Kolviza salmon. This is evidently related to changes in the survival of eggs and fry.

In Table 5 both the initial data for the calculation of coefficients and the coefficients themselves are given.

It is seen that the Kolviza salmon has a somewhat higher coefficient of return though a lower rate of survival. This is no error of computation, but rather the result of an unequal sex ratio in the spawners entering these rivers. Whereas the Tuloma spawners are characterized by an equal sex ratio or a predominance of males, the Kolviza spawners always have an excess of females, so that despite their lower fecundity they have a greater number of eggs per female: 6,090 eggs as compared with 5,200 per female in the Tuloma river. The causes of the predominance of females in Kolviza spawners is a question which we cannot yet answer; there is reason to suppose that precocious males, reaching maturity prior to their descent to the sea, occur in the river Kolviza more often than in the Tuloma river, and that they are therefore exposed to a higher rate of mortality. This does not necessarily imply a post-spawning mortality, heavier losses of males may also be caused by a dulling of the instinct of self-preservation, which is manifested in all fish during the spawning period. It can, however, already be stated that a deficiency of males in a spawning migration has no adverse effect on reproduction. In 1950 the spawning mi-

Table 4. Results of reproduction of six year-classes of the Tuloma population

Year of spawning	Number of spawners	Number of adult fish returned						Ratio of breeders to number of fish in a year-class	Number of fish returning to the river for the 2nd time					% of fish in the year-class	Total
		3+	4+	5+	6+	7+	Total								
1945	2,100	700	1,020	1,432	313	43	3,508	1 : 1.67	11	25	13	26	75	2.1	150
1946	730	490	1,845	1,659	899	104	4,997	1 : 6.34	17	34	78	12	141	2.8	282
1947	1,540	700	2,238	1,611	824	212	5,585	1 : 3.62	25	55	6	—	86	1.5	172
1948	810	1,751	1,128	1,901	642	73	5,495	1 : 6.78	8	19	20	—	47	0.8	94
1949	810	473	2,270	2,360	652	194	5,949	1 : 7.34	6	—	—	?	—	—	6
1950	1,920	514	1,705	2,619	789	?	5,626	1 : 2.93	—	—	?	?	—	—	—

Table 5. Average results of the reproductions of salmon during a period of stable abundance

River	Number of escaped breeders which have produced returning year-classes	Total quantity of eggs in escaped females	Numerical strength of all returned year-classes (number of fish)	Average ratio of return	Average rate of total survival	Percentage of survival to a second migration —range of variations
Kolviza ...	780	4,756,000	3,126	1 : 4.00	0.065	0.12—2.62
Tuloma ...	7,910	41,132,000	31,160	1 : 3.93	0.075	0.70—2.80

migration of the Kolviza salmon contained 80% females, nevertheless the year-class produced by its spawning was five times larger than the number of breeders in the escapement. The spawning beds in the Kolviza are situated in places inaccessible to direct observations. It is therefore impossible to decide whether this was caused by repeated spawning of male migrants or by the participation of precocious males, which have matured before their descent to the sea.

From Table 5 it is seen that the survival of these salmon to a second migration is not high. It must also be noted that in no instance have we observed survivals to a third migration. The rivers Kolviza and Tuloma are not unobstructed rivers. The discharge of the first is partly regulated to the interest of navigation also of an electric station situated on one of its arms, the discharge of the latter is entirely regulated. In both rivers the escapement of breeders to the spawning grounds is achieved by means of fish passes. We have observed a far higher percentage of repeated migrations (on an average from 4.0 to 7.2 %) in unobstructed rivers. This permits us to

infer that an adverse effect of changed conditions of habitat and of descent of spent salmon took place in the rivers Kolviza and Tuloma.

Conclusions

1. Our observations showed that during a period of stability of the stocks investigated, the total survival of salmon averaged 0.065—0.075 % of the quantity of eggs contained in females allowed to escape to the spawning grounds. It is obvious that the average rate of total survival for a number of years must be even lower.

2. Owing to the relatively high fecundity of the females and their predominance in the spawning migration, even a moderate percentage of total survival will assure an average return of migrants four times as numerous as the total number of spawned breeders (males and females).

3. A considerable predominance of females (80% in one of the spawning migrations) had no adverse effect on reproduction.

II. (6)

Survival and Growth of Baltic Salmon of Different Ages in Natural Conditions

By

V. S. IVLEV and G. G. GALKIN

Introduction

The data given in this paper were collected during the years 1955–1957. When organizing this investigation the authors took the following into consideration:—

Owing to artificial propagation of Baltic salmon fish of different ages are being reared at hatcheries. Their release into natural reservoirs (the river) is effected at different stages, beginning with fry at the transition period of active feeding up to individuals migrating to the sea (smolts). For the most part the scale of artificial fish-breeding is limited by possibilities of rearing: by the quantity of physiologically adequate food or by the area of rearing ponds.

It is evident that every hatchery can have either a smaller quantity of big fingerlings or a greater number of small ones. The survival rate of the fingerlings increases, as a rule, with their age. However, the final effect is defined not only by the relative survival but by the absolute number of fish released into the river as well. Thus, the objective estimation of the effect of artificial fish-breeding must be based upon a simultaneous analysis of two variable values: on the possibility of getting some quantity of fish of different ages per unit of fish cultural effort and on the relative survival rate of these fish of different ages.

The definition of the first element presents no great difficulties and may be performed with sufficient accuracy. Therefore our task, as we saw it, consisted mainly in getting objective values of the relative survival rate of fish of different ages in typical natural conditions. Moreover we took it for granted that the return of smolts would be continuous, independent of the age-group of the fish released into the river, from which the smolts migrated.

Information in the literature on the mortality rate of different age-groups record the data concerning one population (McCrimmon, 1954). In this case mortality is not only a function of age but also a

function of specific conditions of the given space of time. In our opinion the most objective data may be obtained only when comparing the mortality rate of fish living together, but which are of different ages when released. (That is, the processes of life and death take place simultaneously and under the same conditions.)

Material and Methods

Our investigations have been carried out in the Peterupe river, which falls into the Gulf of Riga of the Baltic Sea. The Peterupe river is a typical "small salmon river" of a relatively small length, which facilitated the observations. Its total length is 45 km, the level difference from its effluent to the mouth being 54 metres. Its banks are hilly and woody. The river bed is very meandering, sections with relatively sluggish flow alternating with stretches of water with the current rate reaching 1m/sec. The river level is variable, in April and May due to the spring flood, in summer and particularly in autumn, as the result of heavy rain.

There is practically no plankton. The benthos consist both of insect larvae (*Trichoptera*, *Ephemeroptera*, Chironomidae, and others), Gammaridae and Oligochaeta. All these animals, as well as the imaginal insects, falling into the water, serve as food for the parr.

The river has an abundant fish population. It is inhabited in considerable quantities by trout, pike, burbot, perch, roach, ide, three-spined stickleback, and others. Sea trout and lampreys ascend the river for spawning.

Fry and fingerlings of different sizes and ages were released into the river in 1955 (Table 1).

The planting material had preliminary been reared at the "Tome" hatchery. Early fingerlings and fingerlings were marked, the former by means of adipose fin-clipping, the latter by clipping the adipose fin and the three last rays of the dorsal fin.

Table 1.

Groups	Time of release	Quantity	Stage	Length in mm		Weight in g	
				Range	Mean	Range	Mean
I	16. May	150,000	Fry	21—28	25	0.081—0.184	0.138
II	18. July	5,300	Early fingerlings	42—58	50	0.78 —2.40	1.70
III	18. Sept.	1,000	Fingerlings	59—89	70	2.3 —8.6	4.0

Table 2.

Date	Water temperature °C	Level in cm	Quantity of migrating smolts	Total and %
<i>Autumn 1955</i>				
10. X. —19. X.	9.4	96.5	8	30 (4.9%)
20. X. —29. X.	5.7	80.0	6	
30. X. — 8. XI.	2.5	104.0	2	
9. XI.—18. XI.	3.4	73.0	9	
10. XI.—30. XI.	1.1	108.6	5	
<i>Spring 1956</i>				
3. V. —12. V.	6.7	159.5	39	117 (19.0%)
13. V. —22. V.	11.2	123.8	40	
23. V. — 1. VI.	14.8	89.7	33	
2. VI.—11. VI.	17.5	49.0	3	
12. VI.—22. VI.	17.7	43.5	2	
<i>Autumn 1956</i>				
21. IX.—30. IX.	4.6	73.6	0	39 (6.3%)
1. X. —10. X.	3.7	108.7	0	
11. X. —20. X.	4.1	111.2	10	
21. X. —31. X.	2.9	121.9	29	
1. XI.— 9. XI.	1.0	150.0	0	
<i>Spring 1957</i>				
11. IV.—20. IV.	1.0	89.5	2	430 (69.7%)
21. IV.—30. IV.	5.9	61.7	331	
1. V. —10. V.	6.5	79.2	74	
11. V. —20. V.	8.5	54.6	23	
21. V. —30. V.	9.7	37.0	0	
31. V. — 8. VI.	9.7	49.6	0	
<i>Autumn 1957</i>				
1. X. —10. X.	11.2	88.0	0	1 (0.1%)
11. X. —20. X.	10.2	108.4	1	
21. X. —30. X.	10.4	121.4	0	
31. X. — 9. XI.	7.6	78.5	0	
10. XI.—19. XI.	3.6	87.1	0	
20. XI.—26. XI.	1.6	67.9	0	

For the quantitative determination of the seaward migration a permanently working trap was built in the Peterupe river mouth. This trap was examined twice a day: in the morning and in the evening. The trap remained in the river from the beginning of the investigation to the end, being removed for repair only in the periods of stable level (in summer and winter), when no smolts entered the trap. A relatively small rise of the water level during the spring flood (about 1 m) did not disturb its work. In addition a special fence was put up to prevent the salmon from entering the river for natural spawning.

All smolts were trapped and taken for further analyses. As no natural spawning could occur, it was

possible to define exactly to what group each smolt belonged.

To make sure that all surviving individuals had migrated from the river, it was examined by means of electro-fishing in the autumn of 1957, not a single salmon being detected.

The Character and Factors of Seaward Migration

Table 2 shows the results of seaward migration. As can be seen, the migration of smolts from the river took place only in the autumn (10%) and in the spring (90 %), about 70 % of the smolts descend-

ing two years after planting. Migration was observed neither in summer nor in winter (see Table 2).

The principal environmental factor causing migration is the change of river level. In spring, smolts migrate most intensively when the water level rises, and in autumn, when it falls. When the water level is stable, no matter whether it is high or low, no migration occurs.

The dependence of seaward migration upon temperature is not so clear. There is a tendency for migration activity to increase owing to sharp temperature changes, although this correlation may be accounted for by the fact that temperature changes are usually connected with changes in level.

The seaward migration usually takes place during the dark hours. 550 (89.1%) individuals were found in the trap during morning examinations, the evening checking giving only 67 (10.9%). These data agree well with those of other authors who observed the seaward migration of Pacific salmon (Neave, 1955).

The Characteristics of Smolts

Smolts migrating from rivers to the Gulf of Riga never possess any typical silver colour. In addition to a strongly marked silveriness they have obvious dark spots characteristic of parr. Smolts acquire complete silver colour only in the Gulf itself.

It follows from Table 2 that the main part of the smolts descend to the sea at the age of two years. This conclusion fully conforms both with observations of natural migration and with the data of age analysis of the adult individuals (Lishev, 1953). The average size characteristics of smolts are given in Table 3 below. As may be seen smolts become bigger with age. It appears that fingerlings caught in the trap before they are 2 years old cannot be considered real smolts. Their entering into the trap is caused not by typical seaward migration but by their movements in the river under the influence of factors mentioned above.

It is essential to note that the earlier the fry or fingerlings are released into the river, the quicker they grow and reach smolt size. As a rule, smolts from the rivers of the Riga Bay weigh about 25 g

the same weight as smolts from groups I and II, smolts from group III are smaller, about 20 g.

The observations on survival rates are given in Table 4. It is evident from these figures that the mortality rate at the early stages of development is very high. This conclusion is not an unexpected one and is confirmed by both the observation of survival in ponds when fry are planted in them and ample experience of hatcheries which release fry into the river but not fingerlings, nor yearlings, nor smolts.

Table 4.

Groups	Number of specimens released	Number of smolts caught	Survival rate in %
I	150,000	314	0.21
II	5,300	291	5.49
III	1,000	13	1.30

The results of mortality rate from group II proved to be of greater interest. In this case the survival rate was 5.5%, i.e., 26 times greater than that of fry of group I. Hence, even a short preliminary rearing sharply increases the efficiency of fish-cultural work.

The results of the mortality rate of early fingerlings from group III were unexpected. The above figure shows that the survival rate of fingerlings of this group during the observation period was 1.30% less than that of early fingerlings from group II. This difference may be explained by the following considerations.

1. The release of smolts into the river was effected during an unfavourable season (autumn), when acclimatization to new conditions proved to be rather difficult. In particular the temperature of the river water at that time was 4–5°C lower than that of the pond water.

2. A more prolonged rearing in pond conditions, in the absence of predators, reduces the resistance of fingerlings to the unfavourable factors of "natural" conditions. This is an *a priori* assumption not proved by any observations.

3. The method of marking applied produced a traumatic effect, in increasing the mortality rate of smolts of this group. It should be noted that prelimi-

Table 3.

Age from hatching in months	Group I			Group II			Group III		
	Number of specimens	Length, cm	Weight, g	Number of specimens	Length, cm	Weight, g	Number of specimens	Length, cm	Weight, g
7–8.....	21	8.7	7.9	8	7.8	5.6	—	—	—
14–15.....	74	9.4	9.6	39	9.1	8.8	3	8.6	6.9
19.....	20	12.9	26.4	18	12.6	24.6	1	11.0	16.3
26.....	195	12.3	25.3	226	12.2	23.0	9	12.2	20.8

nary retention before release of marked smolts did not demonstrate traumatic effect.

4. Finally, it may be assumed that the increased mortality rate in this case may have been caused by some unregarded chance factors. The release of autumn fingerlings with the average individual weight of 8 g into the same river in 1950 showed 12% survival rate. Hence, the mortality rate of smolts obtained from group III could have been somewhat lower under more favourable conditions.

However, on the grounds of the observation data obtained we can draw the following important conclusion. Even a comparatively short preliminary rearing of fingerlings up to the individual weight of approximately 1.5 g sharply increases their ability to survive under rather unfavourable conditions (a great number of predators). The rearing of fingerlings up to some bigger size though increasing their ability to survive does not give them any serious advantage in the struggle with unfavourable environmental factors.

General Observations

The parr inhabit the Peterupe river in its lower reaches, occupying 1/3 of the river, i.e., about 15 km. The parr mainly keep to stony shallow stretches of water with rapid current and are not met in silted areas. The area correlation of the two is approximately 1:4. The stony stretches are on an average about 10 metres broad. Hence, the total area inhabited by parr was about 3 hectares.

618 parr were obtained from this area, one specimen occupying thus 50 m² on an average.

As said above, considering this density of population the growth-rate is rather high, higher than in the case of pond-rearing. It appears that the density of a parr population may be increased without detriment to their growth, even if there is a great quantity of "wild" fish. In particular 600 *Salmo trutta* parr were caught in the trap and as regards food they were identical with the salmon parr.

Taking the survival rate of 1.5 g salmon fingerlings to be 5.5% it follows that initial planting density should be at least 3 specimens per 1 m² of the river sections favourable for the given species. Evidently, these figures are rather rough and may greatly vary with concrete conditions of any given water. It should be noted that the estimation of the optimum planting density on the basis of estimates of food carried out by ordinary hydrobiological methods is not likely to be possible, the most reliable criterion being direct observations of the growth-rate of the parr.

At present, the question of the optimum size of

the hatchery fingerlings is under discussion. In cases where there is a dam on the river not far from its mouth smolts are just what is needed. However, such conditions are met with comparatively seldom, and usually there are parts of the river which provide a convenient aquatorium for salmon and parr.

On the basis of the results obtained on the survival of 1.5 g fingerlings we can make the following simple calculation. If we assume that the final weight is 25 g and that the annual fish productivity of ponds is 100 kg per hectare, one hectare of the pond area will produce 8,000 smolts in two years. In the same time we can get from the same area 133 thousand fingerlings, each weighing 1.5 g. The survival rate of the latter up to the smolt stage is 5.5%, hence one hectare of the pond area finally gives 7,315 smolts, i.e., about the same quantity of smolts as when reared only in ponds. Moreover, preliminary rearing during a short period is very simple, requiring no wintering of fingerlings and allowing the use of the same ponds for rearing some other fish after releasing the salmon. Employing this method, it is possible to make use of carp ponds since the rearing takes place during the spring months and the main unfavourable factor—the water overheating in July and August—does not exist.

If we assume, according to Carlin (1955, a, b) that the return from the smolts for the Baltic salmon is on the average 5%, and that the average weight of an adult salmon is 7 kg the return from one hectare of the pond area with the fish productivity being 100 kg per hectare, will amount to more than 1,300 kg of high-grade costly fish.

To conclude we are going to mention one more point. Salmon culture is based on a remarkable peculiarity of this fish namely their return to their "mother" river for spawning. According to the latest data of Wisby and Hasler (1954) and Hasler (1954), salmon find their "mother" river owing to some peculiar chemical memory. At present we have no data to help us to define the period during which the salmon parr have to live in a river of a definite chemical nature to enable them to find the river again after their period of life in the sea.

There is some fear that if hatcheries rear smolts either in the water other than that of the "mother" river or in strongly metamorphosed pond conditions and then releases them right into the sea at the river mouth, the smolts will not find their way to the "mother" river.

Summary

1. The main task of the investigation was to define the optimum size for salmon fingerlings reared

at hatcheries. The leading principle of this definition was the estimation of the survival of fry and fingerlings of different sizes in typical river conditions.

2. The investigation has been carried out in the Peterupe river, discharging itself into the Gulf of Riga of the Baltic Sea. 150,000 fry (average weight 0.138 g), 5,300 early fingerlings (1.70 g), and 1,000 fingerlings (4.0 g) were released into the river in 1955, all of them being marked. A trap was put at the river mouth to intercept the smolts.

3. Smolts descending from the river to the Gulf of Riga do not possess any typical silver colour which is acquired only in the gulf. 70 % of smolts migrate to sea at the age of two years. The average length of smolts is 12.5 cm, the weight being 25 g.

4. The principal environmental factor stimulating the seaward migration is the change of the water

level: its falling in spring and rising in autumn. More than 90% of smolts migrate in spring, in autumn less than 10%. No seaward migration occurs during summer and winter.

5. Seaward migration depends upon the time of the day: about 90% of smolts migrate during dark hours, in the daylight about 10%.

6. The survival rate amounted to: fry 0.2%, early fingerlings weighing 1.7 g — 5.5 %, fingerlings weighing 4.0 g — 1.3 %. The last figure is apparently not typical.

7. On the basis of the data obtained for the survival rate and calculations of the efficiency of fingerling-rearing at hatcheries it can be assumed that the greatest effect can be achieved by short preliminary rearing of fingerlings weighing about 1.5 g.

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II. (7)

Young Salmon in the Upper Part of the River Petchora

By

M. I. VLADIMIRSKAYA

Salmon spawn both in the Petchora river itself and in many of its tributaries. The most important of these tributaries, in the upper part of the Petchora river, are the Ylitch and the Uniya rivers. In the Petchora river the spawning grounds are located in its uppermost part, beginning 30 km downstream from the place where the river comes out of the mountains and extending for about 150 km further down the river. This part of the river is rather narrow, only about 50 to 80 metres wide, it is fast running and the river-bed is covered with large pebbles mixed with a considerable amount of larger-size stones. There are many rapids, as well as a few deep pools.

During the first summer after hatching the young fish live in the area of the spawning grounds, but in the following years some fish move further downstream colonizing another 100–150 km, so the main feeding grounds then extend over about 300 km from the source of the river in the mountains. The majority of young fish, however, remain within the area of the spawning grounds and further down the river they gradually become fewer in number. In the best fishing places more than 200 fish were normally caught by a 15 metre seine.

When the water freezes most of the young fish migrate to the pools where the current is slower. At the beginning of June they appear on the rapids. Fish of the 1+ and 2+ age-groups are the first to arrive, and fish belonging to the older age-groups appear at the beginning of July. Until the end of August the young fish remain stationary. Some marked specimens have been caught three or four times in the same place. In the autumn they begin to migrate to their winter grounds, which are mostly further downstream. This autumn migration usually takes place by the end of August, but is sometimes observed in the middle of September. This, apparently, depends upon the cooling rate of the water in the autumn.

In the summer, the typical places where the young fish live are river areas with a fast current, from

0.5 to 1.5 metres deep. The river-bed in these parts is usually made up of large pebbles mixed with a considerable amount of boulders; it is quite stable and covered with sparse weeds. When the water is warm and is at low level the young fish usually remain below the rapids. Unlike younger fish, the larger fish of older age-groups live in the rapids where the current is faster, quite often in the main flow. In summer the water temperature in the Petchora river may rise to 23°C, but this has no adverse effect on the young fish.

In the Petchora river six different age-groups, from 0+ to 5+ years, live together, but the majority of the fish belong to the first three age-groups, the fish of the last three groups being found in small number only. The first-year fish (0+ group) remain apart from the other age-groups and are practically never caught with the usual fishing gear. The percentage of various age-groups, excluding the first year-class, have been estimated and the results are given in Table 1.

Table 1. Percentage occurrence of various age-groups of young fish

Year	1+	2+	3+	4+	5+	Number of fish examined
1953.....	53	36	8	2	1	1,697
1954.....	44	35	14	6	1	2,157
1956.....	47	43	9	0.5	0.5	1,397
1957.....	47	44	8	1	0+	1,600
Average..	48	39	10	2	1	—

The high percentage of the 1+ age-group, observed in 1953, was the result of a great influx of salmon for spawning in 1951. In 1952 the run of salmon was small and therefore, the 1+ year-class in 1954 was also small. In the same year, the fish of the 3+ and older age-groups were found in comparatively large numbers (21%), as were also the smolts. Apparently, this may be explained by unfavourable conditions for the young fish descending to the sea, so that a considerable proportion of the fish remained in the river for another year.

Table 2. Proportion of small mature males and immature young fish in the area of the spawning grounds

Fish	June		July		August		Sept.—Oct.		Winter	
	Number	%	Number	%	Number	%	Number	%	Number	%
Immature (both sexes)	262	80	181	73	203	71	84	27	35	78
Small mature males	64	20	71	27	84	29	227	73	10	22

Table 3. Proportion of females and males, including small mature males, by age-groups

	1+		2+		3+		4+		5+	
	Number	%	Number	%	Number	%	Number	%	Number	%
Females	102	49	288	47	35	26	4	20	—	—
Immature males only	94	90	140	44	39	61	5	31	2	29
Mature males only	11	10	180	56	61	39	11	69	5	71
Males (total)	105	51	320	53	100	74	16	80	7	100

Table 4. Ratio of maturity of gonads in dwarf mature males in ten-day periods

Months	June		July			August			September			Oct.	Nov.	Dec.	Jan.
Ten-day periods	2	3	1	2	3	1	2	3	1	2	3	1	—	—	—
Ratio	—	1.2	3.6	6.3	12.0	14.4	16.7	19.0	—	—	5.4	—	4.0	2.5	2.1

The study of sex ratios in the young age-groups living in the river, is complicated by the gradual increase in the number of small mature males on their way up to the spawning grounds, especially by the end of summer (see Table 2).

The most accurate sex ratio was recorded for the 1+ age-group, in which there were 50 % males and 50% females. In the older age-groups the percentage of males increases as the males stay in the river longer than the females (Table 3).

The relative number of males increases most noticeably in the 3+ age-group, after the majority of young fish of this age-group has already departed to the sea. The proportion of the number of mature and immature males in the area of the spawning grounds also varies month by month. In the summer the former amount to 48%, and the latter to 52% of the total number of males. But in September and October the number of small mature males on the spawning grounds rises to 80%. The immature males, by this time, have already migrated to the wintering places. In December and January the proportion of the two sexes in the catches of fish obtained from the pools is again equal. The process of maturing of the gonads of the males in the summer is rapid (see Table 4).

The maturity stages of the gonads change as follows during the summer: June, I and I—II; July, II—III and III; August, III—IV and IV; beginning of September, IV; end of September, V and VI.

The young fish grow rapidly only during the summer months, i.e., June, July, and August. In September growth becomes slower and later on almost stops completely until the following spring. The annual growth-rate of fish is on the average as follows:

During the first year, 60 mm; during the second year, 37 mm; and during the third year, 30 mm. The respective increases in weight are: 2.8, 7.6, and 15.3 g (see also Table 5.)

Table 5. Sizes of young salmon in June, obtained by direct measurements

Age in years	1+	2+	3+	4+
Average length, mm	60	97	127	161
Minimum	46	78	112	130
Maximum	74	119	156	187
Average weight, g	2.8	10.4	25.7	33.7
Minimum	1.2	5.0	15.6	28.0
Maximum	5.0	18.7	60.3	84.2
Number of specimens	68	233	42	6

The average length of the larvae just hatched from the eggs is 19 mm. Further growth of the fry after they emerge from the gravel, is shown in Table 6.

Table 6. Growth of young fish during their first summer

Date	Number examined	Length, mm	Weight, g
July 11	2	33	0.52—0.53
July 13	5	33—36	0.35—0.55
July 17	3	35—38	0.50—0.65
July 24	3	42—45	0.95—1.15
July 30	4	38—39	0.60—1.15
August 9	4	47—52	1.05—1.75
August 17	3	48—55	1.50—2.00
September 3	3	46—56	1.20—2.00
October 4	2	57—58	2.00—2.20

Scales consisting of a central plate and two sclerites were first seen on fry on 17. July. In September and October the scales had, on the average, already seven sclerites.

Table 7. Fluctuations in average degree of fatness in the different seasons

	Degree of fatness	May	June	July	August	Sept.-Oct.	Nov.	Dec.-Jan.
Immature fish	By Fulton	1.08	1.26	1.33	1.36	1.31	1.26	1.18
	By Clark	0.90	1.08	1.14	1.21	1.16	1.10	1.05
	Number of fish	1	288	173	138	49	8	19
Small mature males	By Fulton	—	1.35	1.38	1.51	1.38	1.28	1.19
	By Clark	—	1.29	1.16	1.20	1.14	1.12	1.08
	Number of fish	—	22	71	85	40	4	4

Growth of the sclerites on the scales of young fish of the 2+ age-group was as follows:—

Average number of sclerites by ten-day periods

June			July			August		
1	2	3	1	2	3	1	2	3
1.3	1.9	3.1	4.5	5.3	6.9	8.7	9.7	10.1

On the average the small mature males show a slower growth of the sclerites than those of the immature young fish, and by the end of August the difference observed amounted to three sclerites. The difference in growth year by year was insignificant. The degree of fatness of the young fish was highest in August and lowest in winter (Table 7.).

The overwhelming majority of fish migrate from the upper part of the Petchora river at the age of three full years, when their average length is 130 mm, and average weight about 25 g. A smaller number of fish migrate at the age of four years (average size 150 mm and 40 g), and some at five years (average size 180 mm and 195 g). Judging by the scales of the adult fish, some young fish migrate at the age of two years, when their average length is 100 mm and average weight is 13 g. The largest specimens descend and therefore the average size of the fish remaining, after the smolt descent, is smaller than the average size of fish of the same generation observed in the previous autumn.

We observed the descent of young fish in the region of the Yaksha village in 1952 and 1956. In 1952 the descent began before 20. June and ended on 5. July. In 1956 it was observed from 10. to 18. June. The hydrological conditions during the smolt descent in these two years were very similar, as follows:—

1952				1956			
Beginning of descent		End of descent		Beginning of descent		End of descent	
t°	Level	t°	Level	t°	Level	t°	Level
16°	120 cm	19°	70 cm	13°	130 cm	19°	60 cm

Young fish move downstream in small shoals (about ten fish in each) at the surface of the water and in the main flow. Usually they were observed in the evening and at night.

Judging by the scales of the adult fish, the young reach the sea in the same summer as they usually have four river rings on their scales. The last ring appears during the run of the smolts. Some adult salmon have on their scales, between the river and the sea rings, one other ring which is wider than the river ring but narrower than the normal sea ring.

In the river, besides the fish of normal parr colouring, some specimens are found with a silvery colouration peculiar to the descending young fish. The degree of silveriness varies from the disappearance of the greenish-golden colour, but with the dark spots on the sides of the body preserved, to complete disappearance of all spots and a light silvery colour normal in the adult fish. This is accompanied by a change in the shape of the body. Smolts may be 2+, 3+ and 4 years old. Their lengths range from 150 to 230 mm, and their weights from 42 to 167 g. The proportion of smolts to the fish with parr colouring increases with age (Table 8).

Table 8. Proportion of smolts and parr in various age-groups (%)

	2+		3+		4+	
	Number	%	Number	%	Number	%
Parr	1,218	100	244	91	51	91
Smolt	2	0+	24	9	4	9

The proportion of the sexes in the smolts was as follows:—

Age	Females	Immature males	Small mature males
2+	2	—	—
3+	11	10	3
4+	2	1	1
Total . . .	15	11	4

The annual growth of parr and smolts, as established by the method of back calculation, is almost the same, but, during the last summer the smolts grow much faster. (See Table 9.).

In the summer the smolts appear in the upper part of the river not earlier than the middle of July. Apparently, these are the fish which should have descended to the sea in the current year, but, for one reason or another, remain in the river. Their

Table 9. Growth of parr and smolts by back calculations

(The figures in italics give the average sizes actually observed)

	Parr					Smolt				
	<i>I</i> ₁	<i>I</i> ₂	<i>I</i> ₃	<i>I</i> ₄	<i>I</i> ₅	<i>I</i> ₁	<i>I</i> ₂	<i>I</i> ₃	<i>I</i> ₄	<i>I</i> ₅
2+	30	92	125	—	—	47	99	200	—	—
3+	32	66	105	143	—	44	76	114	184	—
4+	48	82	113	143	173	42	77	109	146	221

colour change to silvery, had already begun in the previous autumn, as the overwhelming majority of immature fish caught in the last part of September and October are already acquiring the silver colouration.

The young fish feed mainly on insects at various stages of development. Insects have been found in 98% of all the stomachs containing food. Molluscs have been found in 3.6% of stomachs, fish in 4.5%, and vegetation in 2.2%. Insect larvae are the most important and they have been found in 99% of the stomachs containing insects. Adult insects were found in 22% of the stomachs and pupae in 4%. The most important groups of insects are the mayflies (*Ephemeroptera*), chironomids (*Tendipedidae* and *Trichoptera*). In the autumn the chironomids and ephemerids become less important, and during the winter the young salmon live mostly on *Trichoptera*. The amount of food taken varies with the season and the index of stomach content was as follows: June, 209; July, 156; August, 127; September and October, 119; and winter, 98 (cf. Table 10).

The yearlings live mostly on small larvae of Chironomidae, mayflies and stoneflies. In July the number of food organisms found in any one stomach did not exceed 5, but by the end of August it increased to 90. In August the young fish also begin to eat small snails and *Trichoptera* in cases made of sand.

The smolts live mainly on fish, particularly on young grayling which they catch on the rapids. As to the insect food, the smolts eat mainly the larvae of *Trichoptera*, while the insects, the larvae of ephemerids and chironomids are less important in their food.

Among the enemies of young salmon in the Petchora river are fish, birds, and mammals. The loss of salmon

begins at spawning. During the spawning season some of the eggs are eaten by grayling and by small mature males. Grayling, particularly those 20–30 cm long, eat many ova. We found 28 to 90 ova in grayling stomachs without other food at all. All the small mature males caught during the spawning period had some ova in their stomachs; two of the stomachs contained 67 and 59 ova, respectively, and nothing else. According to published data, young fish emerging to the surface of the ground are eaten by *Cottus gobio* L., of which there is a large number in the Petchora river and they live mostly in the same places as the salmon fry.

One year-old salmon are sometimes found in the stomachs of pike and burbot, but they mostly eat young salmon from 10 to 13 cm long, i.e., of the 2+ age-group. According to our data such young salmon are found in the stomachs of 5.1% of all the pike caught in the summer and account for 7.2% of all the fish eaten. These data, however, relate to areas of the river where the parr stay, and where pike are comparatively few in number. Further down the river the number of pike increases considerably, but they only eat smolts when they are descending to the sea. At such times the loss of smolts must be considerable.

There are practically no *Hucho taimen* in the upper part of the Petchora river, but they are usually found in its tributary, the Ylitch river, where a large number of salmon come to spawn. *Hucho taimen* eat young salmon more often than pike (V. P. Teplov, Zoological Journal, 30 (6), 1951). On the average, in the period of three years, from 1948 to 1950, young salmon were found in 24% of the stomachs of *Hucho taimen*, caught in summer and containing food. In one stomach four parr, 12 to 15 cm long, were found.

During the first winter of their life, in the non-freezing sections of the river, the young salmon stock suffers considerably from dippers which drag many of the young salmon and other fish of various kinds out on to the ice. Dippers may catch fish up to 82 mm long. From 24. November to 8. December 1952 ten young salmon of the following sizes were found on the ice:—

Length, in mm	65	75	78	79	81
Number of fish	2	2	3	1	2

Table 10. Maximum weight of food in mg, and index of stomach content by age-groups of fish and by seasons

Age	June		July		August		September—October		Winter	
	Weight of food	Index	Weight of food	Index	Weight of food	Index	Weight of food	Index	Weight of food	Index
1+	100	500	210	436	500	590	—	—	180	—
2+	550	430	610	470	700	271	710	240	250	—
3+	930	288	690	244	290	85	950	212	400	172

Table 11. Loss of young salmon by various predators

Name of predator	Number of stomachs examined	Young salmon found		Number of fish in one stomach	Size, cm
		% of total stomachs	% of total number of fish		
Burbot ¹⁾	79	8.8	100.0	1-3	11-13
Pike.....	192	5.1	7.0	1-2	3-20
<i>Hucho taimen</i>	54	24.1	22.8	1-4	12-15
Dipper.....	{	About 30 young fish pulled out on to the ice, 10 of them young salmon		{	6-8
Merganser.....					10-11
Otter.....	25	8.0	2.2	—	—

¹⁾ The data on the food of burbot was obtained in winter, on the food of the otter during summer and winter, and for the other species in the summer.

A similar incident was observed once on the Ylitch river. Sometimes, young salmon are eaten by mergansers. However, young salmon have never been found in the food of raptorial birds (bald eagle and osprey). Table 11 shows the data on the loss of young salmon by their various enemies, according to the information obtained in the Petchora-Ylitch State Reserve.

Summary

The upper part of the Petchora river and its tributaries are the spawning grounds for large salmon which migrate into the Petchora river in the autumn and spawn the next year. The spawning grounds are located along the first 150 km of the river, from the source of the Petchora river in the Ural mountains (1,650-1,800 km from its mouth), and some of the young fish travel 80-100 km further downstream entering tributaries where salmon do not spawn. The majority of young salmon remain in the middle of the spawning area.

The larvae hatch from the eggs in May, and in July the fry are already seen at the surface of the gravel. During the summer young salmon live on the rapids and in the autumn move to the deep pools where there is a slow current and they stay there for the winter. At the beginning of June, they return to the rapids. The young fish grow rapidly only during the three summer months, while during the winter their growth is considerably slower or may even stop completely. In June the average weights and lengths are:— 1+ age-group, 60 mm and 2.8 g; 2+ age-group, 97 mm and 10.4 g; 3+ age-group, 127 mm and 25.7 g; and 4+ age-group, 161 mm and 33.7 g. Fish of six age-groups, from 0+ to 5+ live in the Petchora river, but the majority are fish of the first three age-groups, while the last three age-groups are present only in small numbers.

In the 1+ age-group the male-female ratio is 1:1. In the older age-groups the males predominate, which is especially noticeable in the 3+ age-group, as some males remain in the river for one to two years after the majority of the fish of their age-group have descended to the sea. The males reach maturity at the age of 2+ years, very rarely at the age of 1+ years. The small mature males also take part in spawning. Ripening of the gonads begins at the end of June or at the beginning of July. In September the number of males on the spawning grounds increases considerably when compared with the summer period.

In summer, in the Petchora river besides parr-coloured fish, a few fish with silvery scales are found. Usually these are the fish of 3+ and 4+ age-groups. Change in colour of the fish begins in the autumn; in the spring these fish descend to the sea and only a small number of them remain in the river.

The young fish descend to the sea when they reach the age of 3 years, a length of 130 mm, and a weight of 25 g. Descent of fish in the region of the Yaksha village has been observed in June and the beginning of July.

In the river the young fish live on insects at all stages of development, but mainly on those in the larval stage. In the food of the larger-size fish, especially those of silver colour, other fish are of great importance.

The fat content of the fish changes month by month, but is highest in July and August and decreases in the autumn; it is lowest in the winter.

The enemies of young salmon in the Petchora river are:— fish (pike and burbot and in the Ylitch river, a tributary of Petchora, also *Hucho taimen*); birds (dippers and mergansers) and mammals (otters).

II. (8)

Considerations Relating to Restocking with Salmon and Sea Trout

By

ST. ZARNECKI

The historical development of the conception of obtaining young salmonid fish by way of artificial hatcheries and rearing ponds and using the material thus obtained for stocking of natural waters shows continuous changes concerning this idea in all its aspects.

At the beginning of artificial breeding, in the XIXth century, it was commonly considered that by this method an instrument of higher efficiency was obtained. The results in practice, satisfactory or not, led to many doubts, so that finally opinions on the inadequacy and even fallacy of this assumption arose.

The character of our symposium allows us to expect a definite indication of what is doubtful and what, on the contrary, may be considered as beyond doubt in the contemporary state of knowledge.

We may state at the outset the chief point of the whole problem. All workers in this field agree that the best method for maintaining the salmon and sea trout populations is the natural spawning and breeding of young fish in suitable natural conditions. Among many generally known aspects of this point of view one of them was, till now, neglected and therefore I would specially like to mention it. The natural spawning process allows for sexual selection in the given species, according to the theory of Darwin. In this manner the specimens of both sexes can choose their partners and this can be of essential value for the adequate adaptation of the progeny and the vitality of the whole population. Natural spawning, often connected with fighting and the victory of the fittest resulting therefrom, presents a mechanism the results of which are undoubtedly advantageous for the maintenance of the species. By artificial stripping and fertilization this mechanism is totally eliminated. In this connexion our artificial method can be considered as acting in the dark. We do not know what direction the development and further maintenance of the species obtained by crossing the parent fish will take, if sexual selection is eliminated.

This does not mean, however, that artificial fertiliza-

tion and stocking of the waters by progeny thus obtained ought to be discontinued.

There exist many situations in which the artificial introduction of young fish may be useful. These cases can be divided into several different groups:—

1. *Virgin waters (without fish).*

Here we have only two ways: the introduction of spawners or of ova, fry, or fingerlings. This last proceeding is nearly always the most practicable.

2. *Acclimatization experiments.*

Here also stocking with fry or fingerlings predominates in practice. Although this problem is not simple in itself and needs further study in many of its aspects, the introduction of young fish remains as the method which, in convenient conditions, may lead to positive results.

3. *Artificial stocking as a supplement to natural spawning.*

In the above-mentioned cases many doubtful points arise. As stated before, we agree that natural spawning is the best way for maintaining the numbers and the normal development of the species. Some workers go so far in this way of thinking as to consider that when spawning is not disturbed by human activities no help of ours can increase the number of fish in the given population by stocking. Therefore we must discuss this matter by dividing the problem into undisturbed and disturbed, or limited spawning.

Disturbed spawning

Disturbances consist chiefly in:—

(a) Obstacles in the rivers, as weirs, dams and the like, which hinder the passing of anadromous spawners to the spawning places. The right way is to free the passage for parent fish by building salmon passes. Although the problem of fish passes is not in itself totally solved, yet the experiences obtained chiefly in

Scotland, England, Ireland, and other countries allow us to recommend it. The catching of spawners below the dams for the purpose of artificial stripping and stocking of inaccessible streams with artificially reared young fish is not as profitable as the above-mentioned method.

(b) The diminished areas of spawning grounds caused by water pollution and regulation of rivers lead more frequently to the catching of spawners and use of artificially obtained progeny for stocking still unpolluted and undisturbed parts of the rivers. This procedure has only limited advantages, or even none at all, as the whole capacity of the remaining parts is already exhausted by the young stages of salmon and trout originating from their own natural spawning.

As a rule, the devastation of spawning places, strictly connected with the elimination of feeding places for young fish involves in consequence the diminution of numbers of the given population, and artificial hatching and stocking can help very slightly, or not at all.

Only the replacement of spawning and feeding grounds by other means, as for instance in Sweden, through a totally artificial river life cycle, may maintain the population. The Swedish experiment in this connexion is very instructive and unique in the history of fishery management.

(c) In countries where the illegal catching of spawners does not allow them to proceed the spawning, an earlier fishing of spawners may be useful.

Undisturbed spawning

An opinion that prevails at present is the following: if the spawning of salmon and sea trout in rivers is not disturbed, we can do nothing better by artificial

stripping, fertilization, hatching, and stocking. This opinion seems to be quite logical and therefore is commonly accepted without discussion. There exist, however, situations in which human activity may improve the results of natural spawning. I see, for instance, two ways leading to this aim. The first consists in introducing material from hatcheries into waters prepared in the meantime by cleansing them of predators and other undesirable species of fish. The second one consists in introducing the stocking material in head waters completely devoid of fish. In this manner we obtain new feeding grounds, unused up till now by spawning populations. The quality of these new areas may be of great value, as they possess a large amount of nourishment and are characterized by the lack of predators and competition of other fish. But it must be stressed that the problem of those "virgin" head waters is, up to now, not quite clear. There are undoubtedly shallow stretches, where during severe winters young fish may be decimated by frost. In other cases, excretions of roots may be harmful, and so on. On the other hand, we know that the main stock of the salmon and sea trout population never reaches all the small tributaries and river sources. I am convinced therefore that at least a part of the head waters in the majority of rivers may be used as natural breeding places for young salmon and sea trout, and that this way of substitution for lost spawning and feeding places elsewhere may prove to be successful. This problem is worth studying.

Finally, I consider it symptomatic that the evolution of ideas concerning artificial fertilization and stocking of rivers with salmon and sea trout, bringing them to their present state (as described above), is similar in the different countries, though independently arrived at.

III. (1)

Salmon Conservation in the Baltic

By

B. CARLIN

All salmon fishing, in the rivers as well as in the sea, is based on the productiveness of the sea. Only a very small proportion of the weight of adult, catchable salmon is acquired before the fish leave the river.

The main object of the rivers is to supply the sea with seed in form of smolts, by which its capacity of producing salmon flesh can be utilized. Thus, the common feature of all methods employed for the conservation of the salmon populations is to ensure that a sufficient number of smolts enter the sea from the river. The position is essentially the same, whether we want to increase the stock, or if our aim is to prevent decrease caused by the use, or even misuse, of the river for other purposes.

The general principle should be to make use of the capacity of the river to produce smolts, as far as it is still possible, and to compensate for the missing or destroyed production capacity by rearing salmon to a more or less advanced stage. But this must be done without interfering with the remaining natural production.

It is not possible to say that one way of stocking, that is releasing salmon in one certain stage of its life cycle, is more effective than another and should be generally preferred. It all depends on the circumstances in the special case.

The limiting factor is usually the accessible area of spawning grounds and of places suitable for the growth of the fry and parr. Under natural conditions, the salmon population will very soon adjust its number to this reproduction capacity. Whatever the bottle-neck may be, we must bear in mind to use the method of protection at this point, or at later stages, but not before.

If the spawning grounds and nursery areas are still intact, but the access to them is blocked, either by natural obstructions or by dams, the obvious measure is to help the salmon to ascend by building fish passes. In some cases a more economic alternative

would be to catch the salmon in a trap and transport them by road past the obstructions. This method has been quite successful in some Swedish rivers.

Fish passes were very useful at a time when only steep falls were exploited for power production, but now also the river reaches with a low gradient are widely used for this purpose, and so the reproductive areas are more or less completely destroyed. We have now in our country reached a stage when very few new fish passes are built, but already existing fish passes are removed since they are no longer of any use.

In some cases the lost reproduction areas may, at least temporarily, be compensated for by using such parts of the rivers or the tributaries, which lie above the natural limits of the salmon migration. This may be done, either by transferring spawners or by liberating eggs or fry. But at least in our country such areas, which are sufficiently suitable for the salmon to grow up in competition with other species, are very rare.

Until quite recently, the artificial propagation of salmon has mostly been restricted to the liberation of large numbers, or rather what appears to be large numbers, of salmon alevin, as an addition to the natural propagation in the rivers. We have no proof at all that all this work, in our country carried out for almost 90 years, has had the slightest influence on the salmon yield. The reason is that the natural spawning from a salmon stock in equilibrium with the production capacity of the river, gives a large excess of offspring. Even a poor year-class, or a population heavily reduced by fishing, is in most cases sufficient to stock the spawning grounds sufficiently to make full use of the capacity of the river to produce smolts. Unless the number of fry hatched in the spawning grounds is too low, which very seldom seems to be the limiting factor, it is quite useless to add artificially hatched fry.

In other words, salmon fry must never be released in areas which have a natural spawning. They may

be released in suitable areas, which for some reason have no natural reproduction, as an alternative to releasing spawners there. We have, however, no experience from our country as to the effectiveness of such plantings.

When it was realized that a large proportion of the mortality during river life occurred in the very young fish, the next step was to rear the salmon fry up to one-summer-old parr or yearlings. Since the losses during rearing can be kept much lower than in nature, this may be a more economic way of stocking such areas which are deficient in young salmon from natural spawning. On the other hand, if there is no such deficiency, there is no more hope of raising the production above the natural level of that particular area than by releasing alevins.

We have in Sweden produced fairly large numbers of one-summer-old parr. They have mostly been released as an addition to natural populations, and we have no experience of releasing parr in suitable areas. We have, however, some figures for the results of releasing parr in rivers which already have a natural parr production. In the years 1949 and 1950, we marked by fin-clipping, 29,000 one-summer-old parr reared in a pond and released them in the river Mörrumsån in southern Sweden. In the following years 88 were recaptured as adult salmon, with a total weight of 800 kg. Nearly all were taken in the river, where every salmon caught could be examined by the local fishery officers. The return was thus 0.3%. We may assume that at least twice as many were taken in the sea without being reported.

The river catches alone would be fairly sufficient to make up for the cost of rearing the parr. In spite of this apparent success, this experiment must, however, not be used as an argument for releasing one-summer-old parr in rivers with a natural reproduction. We do not know how many of these parr survived at the expense of other parr from the natural population. Furthermore, analysis of the scales from the recaptured fish showed that most of them had stayed in the river only during one winter. The competition may thus have been less than can be expected in most other cases.

In the present state of hydroelectric power production in our Swedish rivers, their capacity of producing salmon smolts is already very much reduced. This means that not only are fish passes almost obsolete, but so are the possibilities of releasing salmon in stages which need a further river life. Our future compensation programme therefore relies almost entirely on releasing smolts, which are reared artificially all their lives. Accordingly, our research programme has, to a large extent, been concentrated

upon methods of smolt rearing and on the effectiveness of smolt planting. Our annual output of smolts is now about 300,000. It is calculated to be about two million around 1965 and about four million ten years later. We have now tagged about 350,000 smolts in the Baltic area alone, and got back 15,000 adult salmon. The average return of all tagging experiments made in the spring of 1954 is now 10.4%. The experiments of 1955, which still may give further recaptures, have up to now given 11.6%. The best result of an individual tagging experiment is a little over 25%.

We therefore believe that the lost production of smolts in the rivers can and should be replaced by releasing reared smolts, and we have a rapidly expanding compensation programme based on this assumption.

We must, however, not be content with that, but also extend our knowledge about the sea-life of the salmon, so that we can get the maximum yield of our efforts, and this is where all countries bordering the Baltic must cooperate.

The failure of most salmon planting in the rivers was due to the mistake of expecting a certain percentage return from releasing a certain number of salmon fry or parr, without recognizing the competition they would have to stand with the already existing population. The same problem may also arise when we release salmon smolts ready to start their life in the sea.

If the reproduction capacity of the river, that is the number of smolts produced, was the factor limiting the population in the sea, we may expect the same production in the sea as before, if we can just replace the naturally grown salmon smolts by artificially reared smolts of the same quality, and we might even be able to raise the production level by releasing more smolts. On the other hand, if the reproduction capacity of the rivers were higher than needed to make full use of the capacity of the Baltic to produce salmon, there is no need to replace all the decrease in the natural smolt production by artificial rearing. The percentage return we get from a certain number of released smolts is not a fixed figure, but is dependent on the relation between the total output of smolts, naturally grown as well as artificially reared, and the number of smolts needed for an adequate stocking of the sea. If the output is greater than the need, the competition is heavier, and the return percentage lower. Conversely, even if it were not economic to maintain the salmon stock at its present level by releasing artificially reared smolts, it may still be economic at a lower level.

Only a relatively small proportion of all salmon smolts entering the Baltic will either return to

spawn or be caught by fishing. Most of them by far will die during the sea-life. The number surviving to the adult stage may be determined by the food production of the sea. There is, however, no evidence that the remarkable fluctuations in the salmon stock are caused by corresponding fluctuations in the food supply, and therefore we may suspect that the production capacity of the sea is not fully utilized all the time.

There is, however, a very important bottle-neck in the production chain just at the junction between river-life and sea-life, which ought to be studied more. When the smolts first enter the sea, they have to endure a heavy stress during the time they have to adjust themselves to the new environment. They have to pass through an area densely populated by predators, and the competition for the available food may be stronger than it is later on. We may be able to avoid some of the losses at this stage, either by releasing the smolts off the coast, or by rearing them to a size above the natural smolt size. We have some experiments in progress, which seem to

indicate that this may give an increase in the percentage return which may well make up for the increased rearing costs.

Not only should we use the most effective and most economic methods to stock the Baltic so that we can utilize its power of producing salmon. But we must also see to it that the harvesting of the fruits of this labour is done properly. Unfortunately, the proportion of small salmon taken by the fishery in the sea is a very large one. This is very uneconomic and makes it difficult to get a proper relation between the rearing costs and the value of the yield. Furthermore, the proportion of salmon caught by fishermen from other countries than Sweden is steadily increasing. It is already doubtful if the amount of salmon taken by our fishermen will be sufficient to meet the costs of the smolt production. The future of our compensation programme and of the salmon fishing industry of the Baltic will therefore be dependent upon whether we can come to an international agreement regulating the salmon fishing in the Baltic.

III. (2)

Co-operation in Research and Management of Baltic Salmon

By

ARNE LINDROTH

In the inland freshwaters—at least in Sweden and many other countries—the fishing rights are divided among more or less numerous riparian owners. This has always been a considerable drag on the rational management of the freshwater fishery as a long-sighted conservational view is often in conflict with and impeded by a short-sighted view of pure exploitation. This state of affairs has resulted in the voluntary union of riparian owners into fishery associations of different types for the adoption of a common policy as regards conservation and exploitation of the fish population.

In this respect the Baltic is quite comparable to an inland lake and the private riparian owners to the states bordering this brackish-water sea. Some of its fish populations are more or less stationary coastal forms and produce no international problems but some species undertake long migrations and their populations are exploited by the fishermen of several countries. Here only the salmon will be considered.

The Baltic salmon stock is reproduced in only some of the Baltic countries but is exploited by all. A rough estimate says that about two-thirds of the stock is reproduced in Sweden. The Swedish salmon rivers are little by little reclaimed for hydroelectric schemes and substituted by rearing stations. There seems to be no reason to doubt the possible biological success of this conservation programme, only its economical justification is somewhat uncertain, i.e., from a national point of view, and in Sweden voices are heard warning against an unprofitable liberation of smolts, subjected to some 90% mortality, and not half of the surviving fish being caught by Swedish fishermen. From a national standpoint these voices say that it would be better to liberate 2-crown pieces (the approximate cost of one smolt) into the Swedish fishing harbours—without mortality or foreign exploitation. This talk is more dangerous for the salmon stock than the power plants—the more so as it is or will be true.

As in case of the small lakes the remedy must lie in all forces for good uniting to rescue the Baltic

salmon by aiming to conserve and exploit the stock for the common benefit by means of influencing the populations in the desired directions by the dissemination of satisfactory knowledge of the stock, its recruitment and mortality.

To begin with the last-mentioned our state of knowledge, though not exactly bad, leaves much to be desired.

Our qualitative knowledge of river life, from spawning run to seaward migration of kelts and smolts, is fairly good but the quantitative estimations lack sound foundations; production limits through food and territory shortage, river mortalities and so on are largely unknown as are the cause and extent of their fluctuations. Of special interest would be good information on past and recent smolt production, natural and artificial, of the Baltic countries. In my opinion this survey, very important for many necessary computations and for conservation measures, would lend itself readily to co-operative work, if uniformity be granted by directional instructions or with a common scientist in charge.

In this connexion, however, the river life may be mentioned merely in passing for the chance of the smolt growing to catchable size and surviving the fishery to produce progeny is the focus of our interest. A provisional smolt recruitment diagram (Figure 1) may serve to demonstrate the most important points where further information is needed.

In all likelihood the mortality is concentrated to the first year in the sea. Predation is thought to be the main mortality producing factor. Smolt mortality through birds and predatory fish on the coast are the subject of Swedish field studies. The porpoise hypothesis—still an hypothesis though sometimes claimed to be proved—affords an explanation of the long-time fluctuations in the Baltic salmon stock. The feeding biology and population fluctuations of potential predators in the sea, especially the porpoise, is one instance of urgent research work suitable for co-operation.

Age and growth studies may reveal much of the

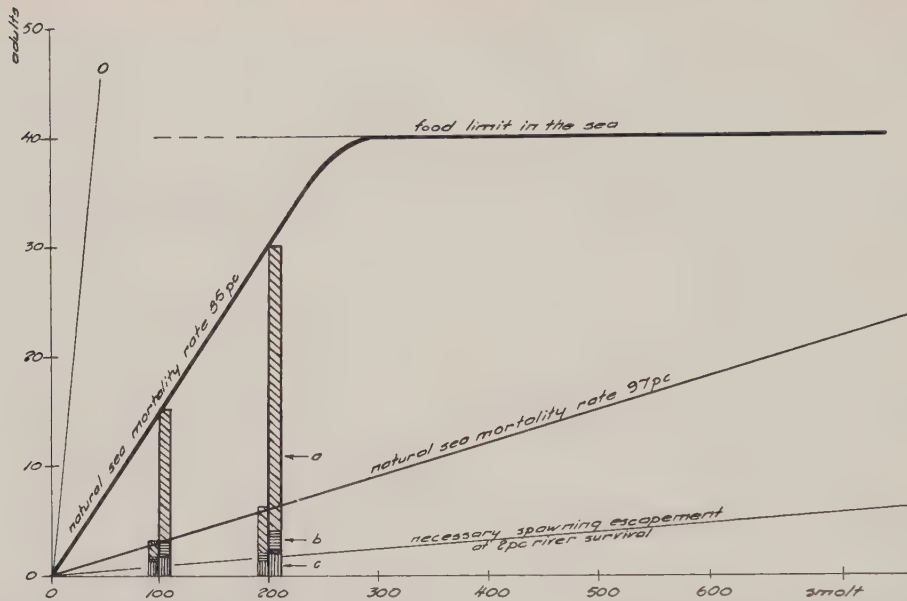


Figure 1. Provisional smolt recruitment diagram. Sea (a) and river (b) fishing mortality and spawning survival (c) indicated at two instances each of smolt recruitment and natural mortality rates. Arbitrary units.

growth conditions in the sea and ought to be extended. As a necessary foundation for such studies, the body growth/scale growth relationship is now being investigated in Sweden.

A remarkable fact is the lack of investigation of salmon food, partly explained by its expensiveness. Such an investigation is, besides growth studies, highly desirable in order to elucidate the probability of a food limit in the sea. Though not particularly probable at the prevailing size of the salmon stock its existence, as the still less likely existence of other limits, would be tantamount to a so-called density-dependent mortality rate (probably executed by predation) better termed density-independent survival. This problem is of the utmost importance for determining the optimum size of smolt recruitment and in the interpretation of its efficiency as learned by tagging.

Whereas the natural smolt mortality rate is probably density-independent (though varying for other causes than smolt recruitment: fluctuations in predator populations, in individual smolt size, and so on) the fishing mortality rate is density-dependent as the fishing effort in the sea and in the rivers varies with, among others, the size of the population fished (shown in Figure 1).

The absolute fishing mortality may be learned from catch statistics, the relative fishing mortality or mortality rate from taggings, both instruments extensively used. In this connexion the importance

of detailed and standardized statistical information including fishing effort and size-group (age-group) of fish may be stressed as well as the prompt reporting of tags recovered.

The interrelations between varying recruitment, mortality by different causes, variability and type, and resultant survival, thus constitute a complex structure of population dynamics whose understanding, though far from achieved, is essential for any interference with the stock and, consequently, for our goal to be reached.

The common and practically only way of influencing fish stocks is by means of fishing. Much more information is needed about mortality rates before we can with certainty decide on the most rational exploitation of the salmon stock. National considerations are pertinent as an exploitation exclusively in the rivers—in case of very low natural adult mortality the right procedure would favour the smolt-producing countries.

To the extent that smolt production is taken over by rearing stations, the recruitment may be positively interfered with. The Swedish investigations seem to prove that liberation of smolts is profitable at the present sea-mortality rates and size of stock. Should the profit, or part of it, land in the country of the salmon culturist, not the practice today anyhow, an increase beyond the legal obligation of hydroelectric companies would probably follow, and would be justified up to certain limits.

Recently, a method of interfering actively with the sea mortality of the Baltic salmon has been presented, implying the killing of porpoises in the Danish sounds. This proposal is based on (1) the porpoise hypothesis mentioned above, (2) the possibility to reduce substantially the porpoise population by hunting. Personally I am not inclined to accept the porpoise hypothesis as proved and I am furthermore sceptical about the requisite reduction of the porpoise stock at will.

Altogether, the Baltic salmon is within reach of positive measures, a state of affairs not at all too common in fishery biology.

The Conservation of the Baltic Salmon and its Exploitation by the Baltic nations seem, thus, possible from the biological point of view in spite of the menace of the shrinking areas of natural spawning streams. In the long run, however, a necessary *conditio sine qua non* must be a fair division of the fishing yield on smolt-producing and non-producing nations so that this production maintains some degree of profit for the countries actively concerned. This is the vital point, the touchstone of co-operation. Some progress has been made at international discussions, their success is a vital condition for the Baltic salmon and for the Baltic salmon fishery.

In this paper the different problems, biological and administrative, have been touched on lightly and without references to earlier work on the subject

which is thought permissible in a survey like this. As a summary I wish to lay before the Symposium the following proposals:—

1. A survey of smolt production in the Baltic countries ought to be undertaken.
 2. Tagging operations, especially of salmon in the sea, ought to be increased to give information on mortality rates of different age-groups. Recovered tags must be regularly and accurately reported.
 3. Predator biology must be studied.
 4. Salmon age, growth, and food investigations are wanted.
 5. Catch statistics ought to be standardized and made more effective.
 6. Loss of original natural spawning facilities ought to be compensated for through liberation of a corresponding number of reared smolts by all nations responsible.
 7. The exploitation must on an international basis be so regulated that such liberations are encouraged, not discouraged. This Symposium ought to impress upon the authorities concerned the importance of this vital question being solved.
 8. Should the establishment of a standing committee on Baltic salmon problems contribute to progress in the respects here mentioned, this Symposium ought to recommend steps being taken to that effect.
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III. (3)

Some Peculiarities of Salmon Biology which are Important in their Reproduction

By

G. V. NIKOLSKY and N. I. KOSHIN

Representatives of the Salmonidae make up about 12% of the total output of fish in the USSR thus providing some valuable food products. They are of great importance as the object of fisheries, both in the Pacific and the Atlantic Oceans. Naturally our fishing industry wishes to obtain high and steady annual catches of these fish. As in other countries, we are attempting to realize this in the following three ways:—

(1) By proper organization of the fisheries and thereby securing catches of fish when they are most sought after commercially. As far as the anadromous salmon are concerned, this implies concentration of fisheries in the river mouths and in the adjacent areas of the sea, where the spawners, migrating to the spawning areas, may be caught before they begin to lose condition.

(2) By ensuring a high degree of natural reproduction by improving conditions for the fish in every possible way.

(3) By artificial propagation at rearing stations from which young fish, capable of living in natural waters, are released.

It is clear that a successful solution of the above-mentioned problems requires considerable research, as well as working out the methods for rearing fish and improving their living conditions. A knowledge of the conditions governing the development of young fish in nature is necessary. This is important in devising methods for increasing the efficiency of natural reproduction, and for improving the techniques of artificial propagation of salmon at the rearing stations.

In our research work we have assumed that the details of every stage of development of any one species may be important in ascertaining the connexion between the species and its environment. This explains why morphological studies have been undertaken to such an extent. By studying all the morpho-

logical features, we can find out under what conditions the organism may best develop.

Obviously in this short report we can only deal with some of the major problems which are now being investigated in the USSR.

In the USSR three species of the genus *Salmo* and six species of the genus *Oncorhynchus* are being reared. As work on acclimatization of representatives of the genus *Oncorhynchus* in the Atlantic Ocean is being carried out in the USSR and in the USA, we will first deal with the representatives of this genus.

1. Sperm and eggs

The quality of the sperm is of vital importance for effective fertilization. The duration of mobility of the sperm is different in the various species. The slower the current in the place of fertilization of the eggs, the longer the sperm remains active in the water. The sperm of the humpback salmon, which spawns in swift currents does not remain active as long as that of the keta (dog salmon) which spawns in a slower current. Sperm of the Atlantic and Far Eastern salmon after they have lost mobility may still be reactivated for a certain period by adding ovarian liquid to the water.

Most male salmon spawn with several females, and therefore their sperm is not liberated all at once, but in several separate portions. Some male Far Eastern salmon have yielded milt good enough for fertilizing eggs in 5 or 6 portions. Thus, when males are scarce, as may happen with Atlantic and the Far Eastern salmon, one male can be used to fertilize several females.

The question of the rôle of small, mature males in fertilization of eggs and of the quality of the offspring produced from them is of special interest. In the spawning areas located in the upper parts of many rivers the small mature males play a very important rôle in fertilizing the anadromous females.

This is so in both the *Salmo salar* and the *Salmo trutta* species.

It has been proved beyond all question that the quality of the offspring which result from fertilizations using the milt of small, mature males cannot be distinguished from those produced by anadromous fish.

In cases where the passage of salmon is obstructed by dams the use of small, mature males reduces the number of migratory spawners which one must bring to the spawning areas from below dams by one half. This question has been more thoroughly dealt with in the report by Koshin and Protasov. (II. (4)).

Morphological and biochemical analyses of the eggs of various salmon species revealed the existence of peculiarities in each species, particularly in their reactions to mechanical influences and to the conditions of respiration.

The salmon eggs which develop whilst buried in large-size pebbles (eggs of humpback salmon and Atlantic salmon) are exposed to great mechanical influences, and they can stand relatively great pressures. In the process of development, the pressure which an egg can withstand varies greatly. (Table 1).

Table 1. Changes in egg strength of various species of salmon

	Before fertilization	2 hours after fertilization	Late morula stage	5 days before hatching	Immediately before hatching
Keta	100 g	700 g	3.5-4.0 kg	2-3 kg	200 g
Humpback salmon...	200 g	900 g	5.5-6.0 kg	8-9 kg	300 g

An essential peculiarity of the eggs of salmon of both the genera *Salmo* and *Oncorhynchus* is that they develop under comparatively unfavourable oxygen conditions which account for their intensive carotinoid pigmentation. The less favourable is the oxygen condition for the development of eggs (*Oncorhynchus nerka*, *Oncorhynchus masu*), the more intensive is this pigmentation. The same phenomenon has been observed within a single species. The eggs which develop under less favourable conditions of respiration show more intensive reddish pigmentation than the eggs developing under more favourable conditions. A knowledge of these peculiarities is of importance in selecting the right conditions for the incubation of eggs at rearing stations.

A remarkable feature of salmon eggs of the genera *Salmo* and *Oncorhynchus* is their ability to "develop" for a considerable length of time without being fertilized. This ability of salmon eggs to live without fertilization is an important adaptation. When

the unfertilized eggs are mixed with fertilized eggs in the spawning redds they stay "alive" and do not poison the normally developing eggs with the products of their decay. The unfertilized eggs of salmon may stay alive for a rather long period, equal to that of the incubation of the fertilized eggs.

2. Specific features of the spawning redds

Investigations of a number of authors have shown that redds of the various species of the Atlantic and Pacific salmon have essential and specific features peculiar to any given species. They also differ within a single species.

A spawning redd is a complicated engineering structure ensuring favourable conditions for the development of eggs.

The redds of humpback salmon differ from those of keta (dog salmon) by a steadier oxygen condition and by a greater concentration of oxygen. On the other hand, the eggs of humpback salmon are more exposed to mechanical influences than those of the keta's. The redds of humpback salmon are located in the regions of erosion of the river bed, while those of keta are located in the regions of accumulation.

The study of the design of and conditions in the redds of *Salmo salar* L. has shown that there are two types in the northern rivers, namely those supplied with sub-terranean water and those without supplies of spring water. So far the connexion of the different species of salmon with one or the other of the above mentioned types of redd has not yet been established. Similarly, keta also have two similar types of redds. The autumn spawning keta deposit eggs in redds with supplies of spring water, while the summer spawning type deposit eggs in redds where the sub-terranean water does not come to the surface.

Studies of the behaviour of the embryos hatched from the shell inside the redds have shown that the salmon usually begin to feed when they are still within the redd. As to the Far Eastern salmon, it was found that both keta and humpback salmon do feed inside the redds. Keta embryos are usually found in the redds in a slanting position with the head upwards, the oil globule being located in the front part of the yolk sac. When an embryo is in a horizontal position, which sometimes happens when fish are reared under artificial conditions, the oil globule moves into the back part of the yolk sac and presses on the intestines, which may impede the passage of food.

By changing the nature of flow, for example, by building small supporting dams, the conditions in the redd may be improved and made more favourable.

Recently some new methods for studying the conditions in redds and conditions for the development of eggs therein have also been worked out.

3. River life of the young fish

As is generally known, the greatest mortality is observed during the river life, but at different stages in various species. As Table 2 shows, the duration of life of the Atlantic salmon in the rivers of the north, varies greatly.

Salmon remain in the Petchora river for the longest time. In any one river the time of descent varies greatly from year to year, and the larger year-classes are spread over the longest time.

Table 2. Age composition of smolts in two northern rivers of the European part of the USSR

(Data from PINRO and VNIORKH)

River	Age				
	1+	2+	3+	4+	5+
Varzuga ..	74.5	25.5	—	—	—
Petchora ..	—	52.0	36.0	10.0	2.0

Table 2 indicates that smoltification is definitely connected with the amount of food available. This question has been considered at greater length in the report by Evropeizeva (II. (2)).

It must be pointed out that although a considerable amount of work has been done to ascertain the causes of smoltification, this problem cannot yet be considered as completely solved. We have just begun to work out methods of controlling it. We believe that this process has much in common with the process of formation of the anadromous forms from small, mature forms (salmon, smelt, anadromous carps, and others), and is connected with alterations in the nature of the metabolism. The time and place of releasing artificially reared fish must be carefully considered in connexion with the ways in which young salmon are destroyed by predators.

It has been established that in the years of high water level in the rivers after spawning time the reproduction is more effective than in dry years. This is explained not only by more favourable regime for the incubation of eggs in the redd, but in many cases also by reducing destruction of fish by predators.

We and Vladimirskaya have shown that in dry years pike feed on neophilic fish, including young salmon, much more than in wet years, when they live mainly on limnophilic fish.

Quite often the period of mass destruction of the descending young salmon is very short. For example, for young keta in the Amur river this period is usually connected with the period of migration of *Brachymystax lenok* into the tributaries, when the latter eat young keta in great quantities, and also with the migration of young keta from the tributaries with clean water into the muddy waters of the Amur river. Here, in the downstream tributaries, which usually have a slow current (the so-called "supported" estuaries), large numbers of young keta are eaten by *Leuciscus waleckii* and by other fish.

The period of mass destruction of humpback salmon quite often coincides with the time of their passage from the mouth of the river into the sea, if this time coincides with concentrations in this area of the spent anadromous smelt (*Osmerus eperlanus dentex*), which feed intensively, and particularly eat large numbers of the descending fry of humpback salmon.

For the Atlantic salmon in the spawning areas of the tributaries of the Petchora river the vulnerable places are rapids, where many of the descending young salmon are destroyed by *Hucho taimen*, and further downstream from the rapids—by pike.

The places occupied by predators and their influence on the stocks of young salmon in the rivers well deserve attention. The solution of this would enable us to select precisely the places to release fish from rearing stations and also to reduce the adverse effect of predators on the young salmon produced by natural spawning.

Experience of a number of countries, notably Canada and the USSR, has shown that control of predators can increase considerably the stocks of salmon produced under natural and artificial conditions.

We have only considered part of those questions relating to the ecology of the river life of salmon, a knowledge which we believe is necessary for the successful operation of rearing stations as well as for improving stocks of salmon produced in natural conditions in rivers.

III. (4)

Developing Effective Use of Hatchery-Reared Atlantic Salmon (*Salmo salar*) in Canada

By

P. F. ELSON

Introduction

1. Principles involved in planting

In Canada, artificial hatching and rearing of Atlantic salmon (*Salmo salar*) were developed on two primary assumptions, (a) that hatcheries assured a much higher survival rate of reproductive products than occurred in nature, and (b) that by liberating more of their products in natural waters the hatcheries assured greater catches of adult salmon. These two hypotheses received general acceptance for many years. The hatchery system was built up to the extent of supplying some 10 millions of young salmon to streams of the Canadian Atlantic seaboard each year.

During the last 20 to 30 years the validity of these ideas has been subjected to critical appraisal. The modern approach demands both quantitative information on the general value of such hatchery practices, and details as to where and how they might be applied to best advantage.

While continuing to operate its extensive system of hatcheries, the Canadian Government has put increasing emphasis on learning how to improve the utilization of these resources. (1).

2. Basic techniques used

(a) *Definition of terms.* While the Canadian hatchery system employs a variety of terms to designate young Atlantic salmon of different sizes, the following will be employed in this discussion:—

Underyearlings—fish with the yolk sac absorbed, but less than one year old;

Small parr; large parr—young fish more than one year old but still in the early freshwater stage; “small parr” if under 10 cm in total length, “large parr” if over 10 cm length; (2).

Smolts—young fish just before or during their seaward migration, and showing various degrees of silvery coating as well as other smolt characteristics;

Post-smolts—fish within their first year after passing

through a smolt transformation, and which have either assumed a normal sea life or remained in streams and reverted towards parr characteristics.

(b) *Fields of study.* Our researches have involved experimental plantings of hatchery-reared young salmon after liberation in natural stream habitats. River systems used for these experiments have included, in the Province of Nova Scotia: the Moser river; in the Province of New Brunswick: the Miramichi river, the Petitcodiac river and especially its tributary the Pollett river.

(c) *Quantitative measurements.* Counts of plantings either directly or indirectly, were made of young fish when liberated in experimental areas. Estimates of parr derived from results of seining in small sample areas were used to evaluate resulting populations at later stages of stream life. These estimates involved systematic seining, usually with the aid of electro-fishing, and processing of data by standard statistical methods. Two types of estimates were used, one based on repeated mark-and-recapture, the other based on catch per unit of effort. Counts of migrating smolts were made by placing weirs across the lower ends of experimental areas and counting all smolts thus caught.

To compare stream populations derived from hatchery plantings with naturally spawned populations, the initial densities of the latter were measured first as “potential egg deposition”, the estimated number of eggs brought into the area by the known number and weight of females present.

Results of Studies of Planting Salmon

1. Supplementary procedures to enhance results of planting

Planting will sometimes give much greater yields of smolts if the liberation of hatchery stock is supplemented by other procedures.

(a) *Selection of particular stocks.* Of prime importance in this connexion is the matter of "homing." Returns to rivers by planted fish of "foreign" origin, which were marked at the smolt stage, have been relatively few. There are no records, however, of such fish having entered freshwater reaches of streams other than the one in which they were planted.

Adaptability of particular stocks to any extreme physico-chemical characteristics of the system to which they are introduced may also be an important consideration. For example, in the Moser river where some tributaries have low pH values during freshet, some stocks survived flood conditions better than others. With underyearlings of comparable size, held under identical conditions during freshet, 80 % from a less acid stream died as acidity increased below pH 4; 55% from a fairly acid river died and only 20% of native stock died. Mortalities ceased as acidity decreased above pH 4. Other factors such as tolerance of extreme temperature conditions may well have similar importance. (3).

(b) *Control of predators.* Sometimes it may be worth while to forestall heavy losses of planted stock by controlling predators. A prolonged study on the Pollett river showed that control of mergansers (*Mergus merganser americanus*) resulted in smolt production from planted hatchery underyearlings being increased by five times or more. It was concluded that merganser incidence exceeding about one bird for each 10 yards width and 10 miles length of stream during the nine months of open water, would reduce smolt production. Similar benefits from control of mergansers accrue to native populations. (4).

(c) *Establishment of stream capacities.* When planting young salmon which are expected to make additional stream growth before migrating seaward, it would seem a waste to liberate more than are required to saturate the productive capacity of the area. Plantings in the Pollett River showed that the productive rate of this relatively fertile stream, with mergansers controlled, was about five or six smolts per 100 square yards of stream bottom. About 25 to 30 underyearlings planted in summer were sufficient to obtain this rate of production, (although two to three times as many underyearlings and twice as many as the six to eight resulting large parr, could be accommodated by the river). Study of native populations in other Canadian Atlantic streams under varying conditions suggests that this rate of smolt production is widely applicable. But in infertile streams the capacity is somewhat less than half that given above, averaging one to two smolts per 100 square yards of stream bottom. (4).

2. Effective planting procedures

(a) *Dispersal of stocks at planting.* Observations of planted underyearlings indicated that they spread about one mile up and down stream within a few weeks of liberation. While some fish moved much farther than this, the more distant ground was not effectively utilized. Yearling stocks planted in summer showed similar limited movement during the first season. In one experiment, planted parr remained in an area originally lacking cover, but to which brush and stone obstructions were added, while they did not remain in similar adjacent areas where no such cover was added. With allowance made for the above factors, planted fish survived as well to smolt stage whether they were poured out at a rate of several thousand in one small spot or the same number were scattered over 1/2-mile of stream. (4).

(b) *Survival rates from planting to smolt run.* For summer plantings of underyearlings to give 2-year smolts, the optimum survival rate to smolt stage was calculated to be a little over five per cent. without mergansers controlled, but about fifteen per cent. with mergansers controlled. In the latter case more fish could be planted, to give five or more times as many smolts as without control. Similar results were obtained for summer plantings of yearlings, but the smolts were produced one year earlier. (4).

For autumn plantings, survival rates were better, being from 20 to 35% to smolt stage when mergansers were controlled. Under these circumstances, similar survival rates to smolt stage were observed for large (7 cm) underyearlings migrating mostly 1½ years later, for large (13 cm) yearlings migrating 8 months later and for large (16 cm) post-smolts migrating 8 months later.

Planting smolts which migrate to sea immediately was successful if the fish were (i) selected during the previous autumn to exceed 10 cm total length and (ii) liberated during the natural period of smolt descent. From 25% to 98% of such fish have been checked through weirs more than 10 miles down river from the planting site within a month of May plantings. When such fish were held over, as post-smolts, until early autumn they did not migrate until the following spring, with interim mortalities amounting to about 65%.

(c) *Planting to remedy specific deficiencies.* Using techniques based on our research activities, it is possible to check the adequacy of local stocks of young salmon in many streams. There is increasing evidence that for best results, hatchery stocks between underyearling and large parr stages should not be liberated in quantities excessive for filling such natural deficiencies as may exist.

When calculated numbers of well advanced under-yearlings were added in autumn to a deficient native population of similar characteristics the survival rate of both stocks, over 20 months to smolt stage, was about 20%. Planting without consideration of existing stocks can lead either to waste of hatchery products or to lack of adequate utilization of rearing areas. Obvious choices for planting are areas where natural spawning has been deficient or absent. Following the principles enumerated above, deficient local stocks may be supplemented with hatchery products at any stage between under-yearling and smolt.

In some Canadian streams extensive forest spraying operations using DDT have resulted in serious depletion of particular year-classes of young salmon. Planting appears to be the only means of restoring the strength of such year-classes. Several considerations are involved because insect fauna, especially parr food, is reduced; there may be residual poisoning effects for some months: small fish are relatively more susceptible to the poison than large. (5).

The implications of hydroelectric development for Canadian Atlantic salmon streams have only recently received close attention. Of two basic considerations, inundation of rearing grounds and interference with

smolt descent, the latter seems at present more important. Planting smolts below the dams, as done in Sweden, seems one obvious remedy.

Ultimate Value of Planted Stock

Useful information has accumulated on the means of using hatchery stock for increasing smolt runs. Large scale, practical confirmation that such enhanced smolt runs will have commensurate value to the desired fisheries has still to be obtained. Some 125,000 marked smolts were liberated from the Pollett river between 1949 and 1956. Of these about 110,000 were of hatchery origin, mostly planted as under-yearlings. Under 15,000 were from native spawned fish. The approximate observed values of these smolts have been as follows: for hatchery-reared stock originating in other rivers 0.02% returned to the planted river, none being recorded in other rivers, and 0.5% were taken in distant commercial fisheries; for native stock in the same stream, 4% have returned to the river of egg origin, none being recorded in other streams and no commercial returns being available as yet.

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III. (5)

Some Peculiarities of the Population Dynamics of the Salmon Stock of the Eastern Baltic

By

M. N. LISHEV

Catches of Baltic salmon vary considerably by years and seasons. This is due to fluctuations in the yields of various year-classes of salmon. Recently the strength of the salmon stock has also been influenced by the fisheries.

The most important stocks for the fishery are the two salmon stocks from the Gulf of Bothnia and the eastern Baltic, respectively. The stock from the Gulf of Bothnia contributes up to 70% of the total salmon catch in the Baltic (Lishev, 1953). The spawning grounds are located in the rivers of the northern and middle part of the Gulf of Bothnia, and the majority of the fry (70%) live in the rivers for three years. The salmon stock of the eastern Baltic contribute 20–30 % of the total salmon catch (Lishev, 1953). The spawning area of this stock extends over the rivers of the Gulf of Finland and of the Gulf of Riga; 70% of the fry remain in the rivers for two years.

Judging from the statistics of catches, the tendency to fluctuate in the yields of various year-classes of these stocks is different, and often opposite. Therefore, in 1929–1930 and 1933–1934 the Swedish catches were low, while they were high in the rivers of Latvia and Estonia. In 1931–1932 the circumstances were reversed, and the large increase in Swedish catches was concurrent with the decrease of catches in Latvia.

The dynamics of salmon populations in the rivers of Sweden and northern Finland, and the factors influencing the yields of year-classes were thoroughly studied (Alm, 1934; Lindroth, 1957; Svårdson, 1955; Järvi, 1938, 1948; and others). There is much less published information regarding the salmon of the eastern Baltic. The dynamics of salmon population in the Daugava river (West Dvina) are discussed in this report. The average annual salmon catch in this river is 600–800 centners. This salmon population is one of the largest of the eastern Baltic stock.

The following two aspects of the problem of the population dynamics are of considerable interest: the influence of the conditions of life of the young fish in the river on the yields of year-classes, and the effect of the fishery on the stock of salmon.

Since the highest rate of mortality in a salmon year-class is observed during the period of life of young fish in the river, the correlations of the yields of year-classes and the following specific features of life of the young fish were studied:—

- (a) river flow during the incubation of eggs;
- (b) flow in the first summer of the life of the fry;
- (c) flow in the second summer;
- (d) temperature conditions in the period of summer feeding of fry.

Fluctuations in catches, yields of various year-classes, and environmental conditions during almost 60 years (from 1886 to 1958, with some intervals) were studied.

1. On the basis of the material studied, 5 natural periods of good catches and 5 periods of bad catches were ascertained.

Good catches were provided by the year-classes of 1888–1889, 1891–1892, 1923–1925, 1927–1928, and 1942–1946; poor catches by the year-classes of 1893–1898, 1918–1920, 1925–1926, 1929–1933, and 1948–1951.

For these periods clear correlation between the yields of year-classes and the total flow for the given period was demonstrated. Rich year-classes coincide with the periods of high river flow, and poor year-classes with low flow.

The interrelation with summer temperature is not so clearly shown, but definitely exists; out of five groups of poor year-classes three coincided with the periods of low flow and abnormally high summer temperatures. In the groups of abundant year-classes, there is not such a clear connexion. This may be

Table 1. Yields of year-classes and environmental conditions (as deviations from normal) in the basin of the Daugava river

Autumn spawning	Yields of year-classes	Flow during incubation	Flow in the first summer	Flow in the first winter	Flow in the second summer	Temperature in the first summer	Temperature in the second summer
1919.....	-	-	--	-	--	++	Average
1920.....	-	-	--	-	Average	++	Average
1921.....	Average	-	Average	Average	+	Average	-
1922.....	Average	Average	+	++	Average+	-	Average+
1923.....	+	++	Average+	-	Average+	Average+	+
1924.....	+	-	Average+	+	Average-	+	+
1925.....	-	+	Average-	+	+	+	Average
1926.....	Average	+	++	++	++	Average	--
1927.....	+	++	++	+	Average-	--	Average
1928.....	+	+	Average-	Average+	Average+	-	Average
1929.....	Average	Average+	Average+	++	Average-	Average	Average-
1930.....	-	++	Average-	Average+	+	Average-	Average-
1931.....	Average	Average+	+	++	++	Average-	+
1932.....	Average	++	++	Average	Average-	+	Average
1933.....	-	Average	Average-	-	Average+	Average	Average

Key to deviations from normal:

++ = very high

+ = high

Average+ = above average

Average = average

Average- = below average

- = small

-- = very small

explained by the nature of the correlation between the amount of summer flow and summer temperatures. During the period under consideration there were 37 cases of low summer flow and 30 cases of high flow. In 65 % of the cases of low flow the temperature was above normal; in 13% it was average. As for high flows, 44% of them coincided with low summer temperature and 27% with average.

2. For thorough analyses of various year-classes, the year-classes of 1919–1933 and 1941–1952 were selected; these are the periods when fishing in the river was well developed.

The data for the first period are shown in Table 1. This period proved to be very convenient for analysis, because at that time the fishery had no noticeable influence on the stock. As is shown in Table 1, there is a number of clear correlations between the yields of generations and the environmental conditions.

In 75% of the cases (3 out of every 4) abundant year-classes were concurrent with high flows during the period of egg incubation, the first summer in the life of the fry, and the first winter of the fry.

As to the poor year-classes (5 cases), there is a very clear correlation with the flow in the first summer of the life of the fry (all 5 cases were coincident with low summer flows); there is, also, a connexion with flow in the second summer, but not as pronounced as in the first summer.

Average yields of year-classes are correlated mainly with flows above normal.

In the period studied the yields of year-classes had no clear or specific correlation with the summer temperatures.

On the basis of the data studied the following statements can be made:—

(a) Abundant year-classes usually appear in the years when flows are high.

(b) The conditions of life during the first summer have a great effect on the mortality of the fry. Low summer flows may completely counter-balance the good conditions of incubation. As a rule, in the years of low summer flow, the year-classes are poor, whereas in the years of high flow the year-classes are abundant or average. Apparently this is one of the main factors.

(c) The conditions during the first winter of the fry also seem to influence the yield of year-classes; if river discharge in this period is low it usually results in poor year-classes.

(d) Flow in the second summer does not matter.

(e) Judging from our data, there is no clear correlation between the summer temperatures and the yields of various year-classes. However, there still exists some general connexion.

For the second period, the pattern of such correlations is somewhat more complicated, since from 1947–1949 the salmon fishery, especially the marine fishery has greatly developed and has begun to have a noticeable effect on the composition of the spawning stock and on the numbers of spawning fish in general.

However, correlation between the yield of year-classes and the river flow during the first summer of the life of the fry existed in 8 out of 11 years of

observation, i.e. the major role of this factor was clearly shown in this period.

Correlation between flow during the period of incubation and the yield of the year-class was only noticed in 5 cases.

In general, during this second period actual and anticipated catches (as foretold on the basis of the conditions of life of young fish in the river) coincided in 7 cases out of 11.

To judge by the conditions of the life of young salmon in the rivers, it is hardly possible to expect abundant year-classes of salmon in the Daugava river in the near future.

On the basis of Järvi's data (1938) on fluctuations in the yields of salmon year-classes of the Gulf of Bothnia stock, the following conclusions are made:—

(a) For the period of 1914–1928 5 year-classes out of 15 were rich and 3 poor.

(b) Out of 5 rich year-classes 4 coincided with the years of high water level, and 1 with the year of average water level in the rivers.

(c) All three poor year-classes coincided with the years of low water level in the rivers.

(d) Out of 7 average year-classes 4 were connected with the years of medium water level in the rivers.

(e) Correlation between the yields of year-classes and temperature conditions is more clearly shown than in our data; all the abundant year-classes correlate with low temperatures, and all the poor year-classes with high temperatures.

This may be explained by the fact that in Järvi's data the correlation of flow and temperature is very clear; all the years of low flow were characterized by high temperatures, and out of 6 years of high water level the temperature was below normal in 4 cases. Thus Järvi's data correspond rather accurately with ours.

3. Let us now consider some data regarding the influence of the fishery on the composition and density of the population of the salmon spawning in the Daugava river.

(a) In 1936–1941 a considerable decrease of river flows and a marked increase of summer temperatures were recorded. The year-classes of these years (catches of 1942–1947) should consequently have been quite poor. The catch in 1946–1947 was, however, considerably higher than was forecast by long-period observations of the population dynamics and environmental conditions. In 1942–1946 conditions in the rivers were favourable, and in 1948–1951, on the contrary, higher catches were anticipated than were actually obtained.

The development of the fisheries proceeded as follows: in 1942–1946 the marine fishery of salmon in the southern Baltic was rather insignificant; the fishery in the Daugava river was also reduced during the second World War. But in 1947–1953 the marine fishery in the southern Baltic greatly increased.

Thus the above-mentioned discrepancies between the anticipated and the actual catches are well explained by the changes in the fishery.

Owing to the neglect of fisheries as well as to the small extent of the marine fishery during the war, an increase in the actual catches in 1946–1947 as compared to those anticipated took place, in spite of the fact that this period was unfavourable for salmon yields.

On the other hand, the reduction of catches in 1949–1951 as compared with those anticipated agrees well with the fact that a considerable amount of the fish was caught in the sea, in the feeding areas.

(b) The increasing effect of overfishing the feeding salmon on the strength of the spawning stock is also indicated by the changes in the composition of the spawning stock during the last nine years. Thus, in 1948–1950, 35–45% of the spawning stock in the Daugava river consisted of salmon which had lived in the sea for 4 years or more. In 1954–1955 the number of salmon of such an age decreased to 20–22%.

Judging from these figures, the intensity of the marine fishery for salmon of the Daugava river population increased during these years twice or more. Accordingly, catches of the spawning salmon in the Daugava river, per net, decreased three times as compared to 1947–1952.

Our information on the effect of fishing on the salmon stock in the eastern Baltic is in accordance with Dr. Carlin's data, which the author had a chance to study during his stay in Sweden in 1958.

From the above-mentioned the following conclusions can be drawn:—

1. The yields of various year-classes of the Baltic salmon of the two main stocks are clearly correlated with the amount of the autumn/winter and especially of the summer flow of rivers (in the first summer of the life of the fry).

2. There is also a correlation with the temperature conditions.

3. In their present form the above-mentioned correlations are still of a formal nature, but they are quite trustworthy. It is necessary to explore the mechanism of the effect of flow and temperature on the mortality of salmon fry in the rivers.

The effect of the summer flow, probably works

through the conditions of the feeding of fry, possibly also through predators.

4. The interconnexions discussed above may be used for predicting the yields of year-classes by years, as well as by periods of years.

5. During recent years fisheries have developed so much, as compared to the strength of salmon stocks that they have begun to influence noticeably the quantities of salmon year-classes.

Until 1944–1948 the strength of the Baltic salmon stock was chiefly determined by the conditions of life of the young fish in the rivers (mainly during the first year of their life).

At present, the effect of the fisheries on the quantities of Baltic salmon is greater in a number of cases than the influence of natural factors, i.e., the conditions of life of young fish in the rivers.

6. Thus, in order to keep the stock of the Baltic salmon on a favourable level, it is necessary to control the fishery, and first of all to limit the marine fishery of the feeding salmon in the southern Baltic.

Summary

1. The conditions of life of the young salmon in the rivers represent one of the main factors which determine the richness of the salmon year-classes and, consequently, the strength of the spawning stock.

2. In the salmon population of the Daugava river (one of the largest local populations of the Baltic salmon) distinct correlations between the yields of the salmon year-classes and the regime of river discharge during the period of incubation and in the first summer of the fry are observed. The second correlation is, obviously, more essential, its effect being greater than that of the first one.

3. Low river discharge is usually concurrent with a poor year-class, and high river discharge with a rich year-class.

4. There is a correlation with the summer temperature of the environment: poor year-classes usually coincide with high temperatures during the first summer of life of the young fish.

5. These correlations, as they are discussed in this report, seem to be of a formal nature, but they are quite trustworthy. It is necessary to decipher the mechanism of these correlations, especially in respect to quantities.

6. In the Gulf of Bothnia and the eastern Baltic stock the correlations of the yields of the year-classes and the conditions of life of the young fish in the rivers are, on the whole, of a very similar nature, although the trends of the population dynamics in these two stocks do not often coincide.

7. The above-mentioned correlations may be used for prognosticating the fluctuations in the yields of various year-classes of the Baltic salmon.

8. In recent years the effect of the above-mentioned factors on the quantities of salmon became out-balanced by the powerful influence of the marine fishery on the salmon stock. The intensity of the marine fishery of the eastern Baltic salmon during recent years had increased twice or more.

Fishing affects both the general strength and the composition of the spawning stock.

9. Judging from the conditions of the life of the young fish in the Daugava river in the years to come, the salmon year-classes of this population will not be abundant. This is also true for the salmon remaining in the rivers of the Gulf of Finland.

It is, consequently, necessary to pay great attention to the control of fishery of the salmon stock of the eastern Baltic.

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III. (6)

Summary of Observations on Trout in the Isojoki (Finland)

By

REINO RYHÄNEN

Studies on trout initiated by the Board of Agriculture Bureau for Fishery Investigations and the Fishery Foundation have been continued in a small river system draining into the Gulf of Bothnia (Isojoki: XXXVII water district, Olin, 1936). The first observations were made before the second World War, but investigations proper were begun 1947, when data regarding the chemical and physical conditions were obtained from the whole district.

The waters of the Isojoki flow into the Gulf of Bothnia about 8 km south of the town of Kristiinankaupunki. The total area of the district is 1125 sq. km, of which only 0.4% is water. In the absence of lakes forming base-levels, the whole system of rivers and streams is extremely liable to flood. After rains sea trout are therefore sometimes able to enter the river even in the middle of the summer. There are several low dams in the river without any fish passes.

Since in Finland there is little variation in the average yield for long periods in the same river basin, the mean water volume can be calculated by multiplying the area of a district by its average yield as follows:—

$$Q = F \cdot q,$$

where Q is the water volume in litre/sec., F the area of the basin in sq. km and q the average yield in litre/sec. per sq. km. In the basin of the Isojoki the average yield is about 8 litre/sec. per sq. km (Siren, 1955). Consequently, the mean water volume of the Isojoki at its outflow into the Gulf of Bothnia is about 9 m³/sec. The areas and the mean water volumes of the water districts of the main river and its tributaries are shown in Table 1 (see also Figure 1).

With the exception of the clear brooks in the area of the source, the water of the Isojoki is brown in colour owing to the presence of humus colloids from wide expanses of peatland. Furthermore, it is poor in electrolytes and slightly acid. These properties are more or less characteristic of almost all the rivers flowing into the Gulf of Bothnia. The oxygen content is relatively high even in winter, although

Table 1. The areas and the mean water volumes of the basin of the Isojoki and its tributaries

Place	References in Fig. 1 Nos.	F sq. km	Q m ³ /sec.
Isojoki above Uuronjoki . . .	(10)	170	1.4
Uuronjoki	(9)	200	1.6
Isojoki above Karijoki	(5)	530	4.2
Karijoki	(4)	225	1.8
Isojoki above Kärjenjoki . . .	(3)	760	6.1
Kärjenjoki	(2)	260	2.1
Isojoki, outlet to sea	(1)	1,125	9.0

in the slowly running brooks in the area around the source of the Kärjenjoki the oxygen supply becomes exhausted in the middle of the winter. The limit of visibility varies between 0.5 and 1.5 metres. Certain figures showing the quality of the water according to observations made during the winter of 1947/48 are given in Table 2. In addition to the main stream and

Table 2. Colour, electrolytic conductivity and pH of the water in the Isojoki district

Place	References in Fig. 1 Nos.	Colour of the water mg/l Pt	Electro- lytic conduct- ivity μS	pH
Lylyluoma	(20)	60	—	6.4
Lohiluoma	(19)	50	—	6.5
Isojoki	(18)	80	38	6.4
Riitaluoma	(17)	70	63	6.8
Isojoki	(16)	70	63	6.7
Katteluluoma	(15)	80	62	6.8
Haukiluoma	(14)	400	92	5.3
Isojoki	(13)	100	36	6.4
Keisahainen	(12)	0	98	6.7
Isojoki	(11)	50	61	6.7
Isojoki	(10)	60	58	6.6
Uuronjoki	(9)	110	61	6.5
Isojoki	(8)	90	60	6.6
Pajuluoma	(7)	160	62	5.8
Isojoki	(6)	90	50	6.6
Isojoki	(5)	80	59	6.6
Karijoki	(4)	170	86	6.6
Isojoki	(3)	90	57	6.7
Kärjenjoki	(2)	320	73	5.9
Isojoki	(1)	130	66	6.6

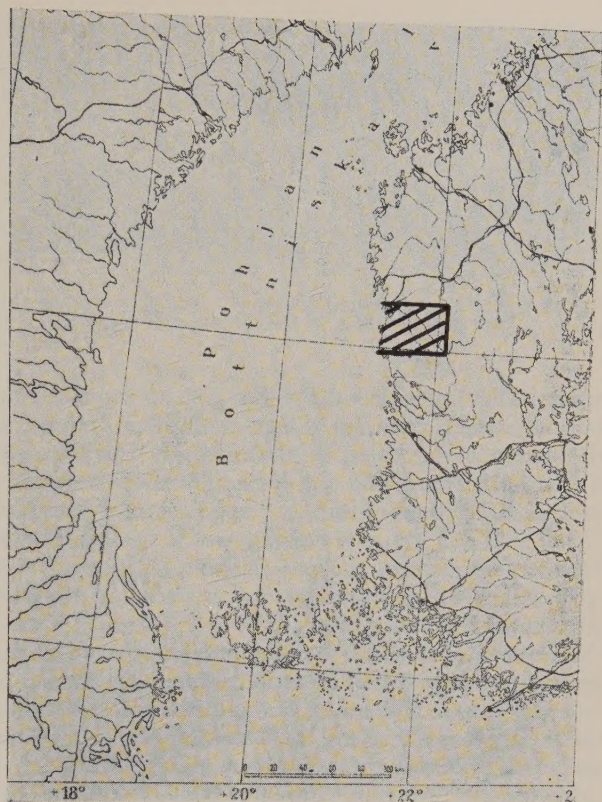
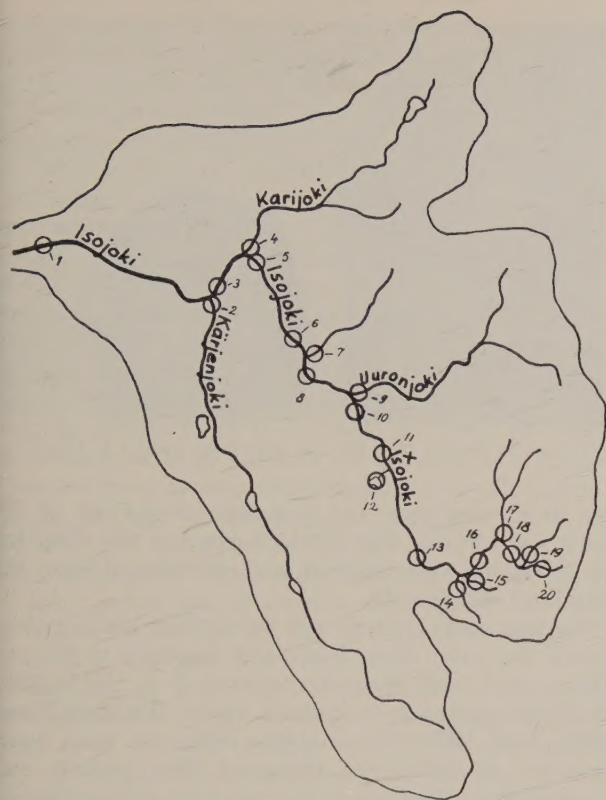


Figure 1. The basin of the Isojoki.

its tributaries, certain streams in the upper part of the system are included because observations on the river trout will be reported below.

The most rapid part of the river is its middle flow (between points 5 and 6 in Figure 1), where there are five rapids within a total distance of 4 km and a total fall of 23 m.

In addition to the sea trout and the river trout, the grayling (*Thymallus thymallus* (L.)) is found in this river, most abundantly in its middle reaches. The pike (*Esox lucius* L.) occurs in all parts of the river system in question, the swift streams in the area of the source excepted. It is even found in the small streams on the large moors which in summer dry up almost to pools. The perch (*Perca fluviatilis* L.), the roach (*Rutilus rutilus* (L.)) and the bleak (*Alburnus alburnus* (L.)) are common in the lower and middle reaches of the river. The ide (*Leuciscus idus* (L.)) and the bream (*Abramis brama* (L.)) occur only in the lower reaches near the mouth.

The burbot (*Lota lota* (L.)) is common throughout the river system and has occasionally been found even in the streams near the source, but in the small dark lakes of the Kärjenjoki it is absent. The brook

lamprey or pride (*Lampetra fluviatilis planeri*) is relatively common both in the main stream and in its tributaries. The lampren (*Lampetra fluviatilis*) is generally found only in the lower reaches, where it is caught, but in summers with an exceptionally high water level it has ascended as far as point 6 (Fig. 1). Of small fish, mention should also be made of the stone loach (*Nemachelus barbatulus* (L.)) and the Miller's thumb (*Cottus gobio* L.), the former being commoner and occurring even in the streams at the source. The crayfish (*Potamobius fluviatilis* (L.)) was also very common, but in the years 1954–1955 the whole population perished in an epizootic destructive to this species.

The sea trout ascend their spawning river to some extent during the floods in May, and in exceptionally rainy years also in the middle of the summer, but the majority do not go up until September. Spawning mostly occurs in the most swiftly flowing part of the river (between points 5 and 6, Figure 1), but some of the fish continue their journey as far as the upper course of the Uuronjoki. At the Uuronjoki–Isojoki junction the sea trout nowadays choose the Uuronjoki, which has a somewhat larger volume of

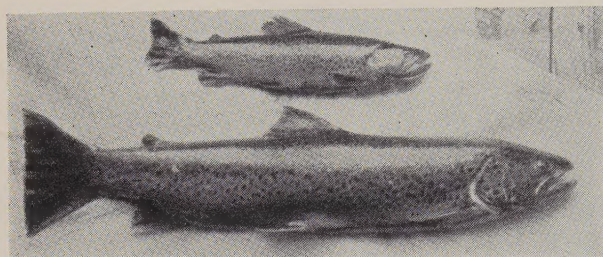


Figure 2. Pair of spawning trout found in the same spawning place. ♂ 385 g, ♀ 4,200 g (before the spawn was collected).

water. They also ascend the Karijoki to some extent, but not the Kärjenjoki. Since the water volume of the latter is larger than that of the Karijoki (cf. Table 1), it seems that the high humus concentration in the Kärjenjoki must be responsible for this (cf. Table 2). The rapidly flowing water of this stream is intensely brown (colour 320 mg/1 Pt) and acid (pH 5.9). The sea trout do not ascend the tributary streams along their route.

The sea trout which have entered the river in the spring spend the middle of the summer in the rapids where these are deepest or in the quiet waters between them. Towards the end of the summer they often gather in the twilight just above the rapids.

In the rivers flowing into the Gulf of Finland the sea trout mostly spawns in October, in the Tornionjoki (Bothnian Sea) either before or after 1. October (Segerstråle, 1937). In the Isojoki the sea trout generally spawns during the last days of September, when the temperature of the water is about 8° C. Spawning occurs where the river bed is gravelly and the water very shallow, often only 10–15 cm deep. Sometimes the back and the tail of the spawning fish are visible above the water surface. The spawning places in the rapids are the same year after year, and often several pairs of fish spawn in the same place. In the most typical cases gravel and spawn accumulate in crescent-shaped elevations behind the spawning fish. Two or three weeks later the river trout (*Salmo trutta fario*) spawns in the same sites. In the second half of October their smaller spawn is found in the uppermost layers of the gravel mounds grubbed up by the sea trout. To what extent the trout is capable of destroying the spawning places of the sea trout by rooting up the layers of gravel which are on top of the developing spawn is a question that still remains to be answered.

However, the male river trout have already attained spawning maturity when the sea trout spawn at the end of September and eagerly attempt to participate. The fish shown in Figure 2 were found in the same spawning site. The lower one is a 5 summer-old female

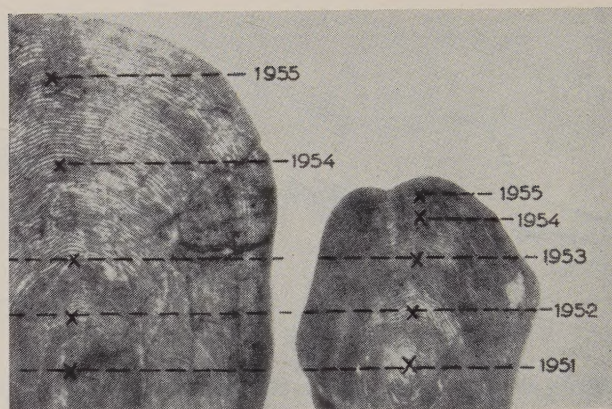


Figure 3. Scales of a pair of spawning trout (cf. Fig. 3).

sea trout, the upper one is a male river trout of the same age (cf. also Fig. 3). Last summer the offspring of this pair were marked and introduced into the rapids of the Isojoki.

Various observations have shown that the sea trout leaves the river of its birth and migrates to the sea after 1 to 7 years. Even in the same river, the number of fingerling years spent there varies (Huitfeldt-Kaas, 1927; Nall, 1934). The majority of the sea trout seem, however, to follow the habits of their parents and migrate from the river to the sea after a fixed fingerling period. According to Järvi's (1940) investigations, more than half the number of sea trout in the Bothnian Sea have spent *four* years in the river where they were born, although a considerable number migrate after three fingerling years, and a few individuals spend their first five years in the river; Segerstråle (1937) found that the sea trout in the rivers of the county of Uudenmaa (Gulf of Finland) migrate to the sea at the age of two years, whilst the sea-trout fingerlings of the Carelian Isthmus spend three years in their native rivers.

According to Järvi, the time of migration is dependent mainly on the size attained: "Migration from the river to the sea is determined by the size attained, the most rapidly growing individuals migrating after three years, individuals with slow growth after five years, and those with moderately rapid growth after four fingerling years" (in the Bothnian Sea). Thus the amount of food available seems to be the main factor determining the length of the river stage, and this, in turn, is dependent on both the population of sea-trout fingerlings and the number of their competitors for food as compared with the amount of food available in the area. The temperature of the river water is also of significance. From the southern parts of the Baltic it has been reported (Hessle, 1935; Alm, 1936) that in exceptional

cases the sea trout may even migrate to the sea after one fingerling year, although the majority spend two growth periods in the rivers there.

The number of trout scales collected from the Isojoki system is still small (totalling 28 specimens), and does not as yet justify any definite conclusions. The fish investigated were obtained from the most rapid parts of the river (between points 5 and 6, Figure 1). With one or two exceptions, they had been caught in late summer or autumn. With the exception of three individuals, which had spent three years in the river, the sea trout in question had attained the size for migration after two fingerling years in the Isojoki. Thus, as a rearing place for sea trout the Isojoki seems to resemble the rivers in somewhat more southerly parts of the country. The length of the sea trout investigated determined by calculation, was an average of 9.0 cm after the first fingerling year and 19.0 cm at the end of the second year. The three individuals which had remained in the river for three years had attained a mean length of 26.2 cm. None of the fish in this material had migrated to the sea after one fingerling year.

According to Järvi's investigations, sea trout which have spent four years in one of the Bothnian Sea rivers have a mean length of 20.0 cm. Compared with these, the sea-trout fingerlings hatched in the Isojoki had thus grown twice as rapidly during their river years.

It cannot yet be definitely stated whether the last ring in the scales, showing more rapid growth, developed during the summer after the fish had entered the river. Since the scales in the material were clearly of two different types, some scales having a relatively narrow last ring, whilst in others the last ring was almost as broad as the preceding ring, which showed more rapid growth, it is here presumed that the last ring had developed during the summer when the fish ascended the river. Individuals ascending in spring grow less during the summer of the same year than those ascending in autumn.

Most of the sea trout here concerned had entered the Isojoki after spending two complete growth periods in the sea. Their weight varied between 2.8 and 4.2 kg. Eight individuals had been in the sea for three years before ascending the river. As calculated from their scales, the mean length of the fish was 36.2 cm after their first year in the sea. Thus, in this period the majority of the sea trout investigated had attained the minimum size stipulated by the Finnish fishery law. Only five individuals would have fallen below this limit after one year in the sea. During the second year in the sea the fish had attained a mean length of 54.1 cm.

In the areas to which the sea trout ascend, the

river trout of the Isojoki grow at the same rate, broadly speaking, as the sea-trout fingerlings. (Those which do not migrate to the sea are here regarded as river trout.) Figure 3 shows the scales of the pair of trout found in autumn 1956 at the same spawning place. It is seen that during their first two years the two fish had grown at more or less the same rate, but in autumn 1956 there was a weight difference between them of 3,815 g (cf. also Fig. 2), the male (river trout) weighing 385 g and the female (sea trout) weighing 4,200 g (before the spawn was collected).

The river trout occurs in the middle and upper courses of the Isojoki and in the numerous tributaries flowing into the main stream. But it is absent in the Kärjenjoki part of the system. In the area where the main stream has its source the river trout has populated even the smallest of the permanent streams. Of the streams in the source area only the Haukiluoma (cf. point 14, Fig. 1) has a humus concentration which is too high for the river trout (colour of the water 400 mg/1 Pt, cf. Table 2). It has been observed that the river trout, too, migrate at the time of spawning, inasmuch as they ascend from the streams at the source to spawn in small tributaries, from the main stream into minor streams, and from the lower course of the main stream ascending upstream, etc. The growth-rate shows wide variations. In the main stream a 4-year-old individual, for instance, may weigh 410 g, whilst an individual of the same age in the streams at the source weighs only 160 g.

Striking variations also occur in the population. It may be mentioned that in 1954 sea trout entered the river in very great numbers. The next summer, fingerlings from that summer were found in the spawning rapids in exceptional abundance. One year later this age-group was still numerous, but in late summer the population suddenly decreased. The most probable explanation of this is that the majority of the fish had migrated to the sea. At present, however, there is an exceptionally large population of *river trout* of the same age-group, weighing about 400 g.

The Board of Agriculture has arranged for the continuation of these investigations of the trout in the Isojoki. This year experimental markings have been made, 162 2-summer-old descendants of the trout pair shown in Figure 2 being introduced into the river. A few of these individuals have already been caught in various parts of the stream. It is only to be regretted that the marking devices employed, which were of Swedish type, consisting of a plastic plate attached with wire, do not seem to be suitable for trout fingerlings in a river such as this where the large amounts of algae tend to get entangled in the wire when the fish are hiding.

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